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TECHNOLOGY · MUSIC · COMPUTERS

No. 58

LECTRONICS

The Maplin Magazine

Britain's Best Selling Electronics Magazine

OCTOBER 1992. £1.75

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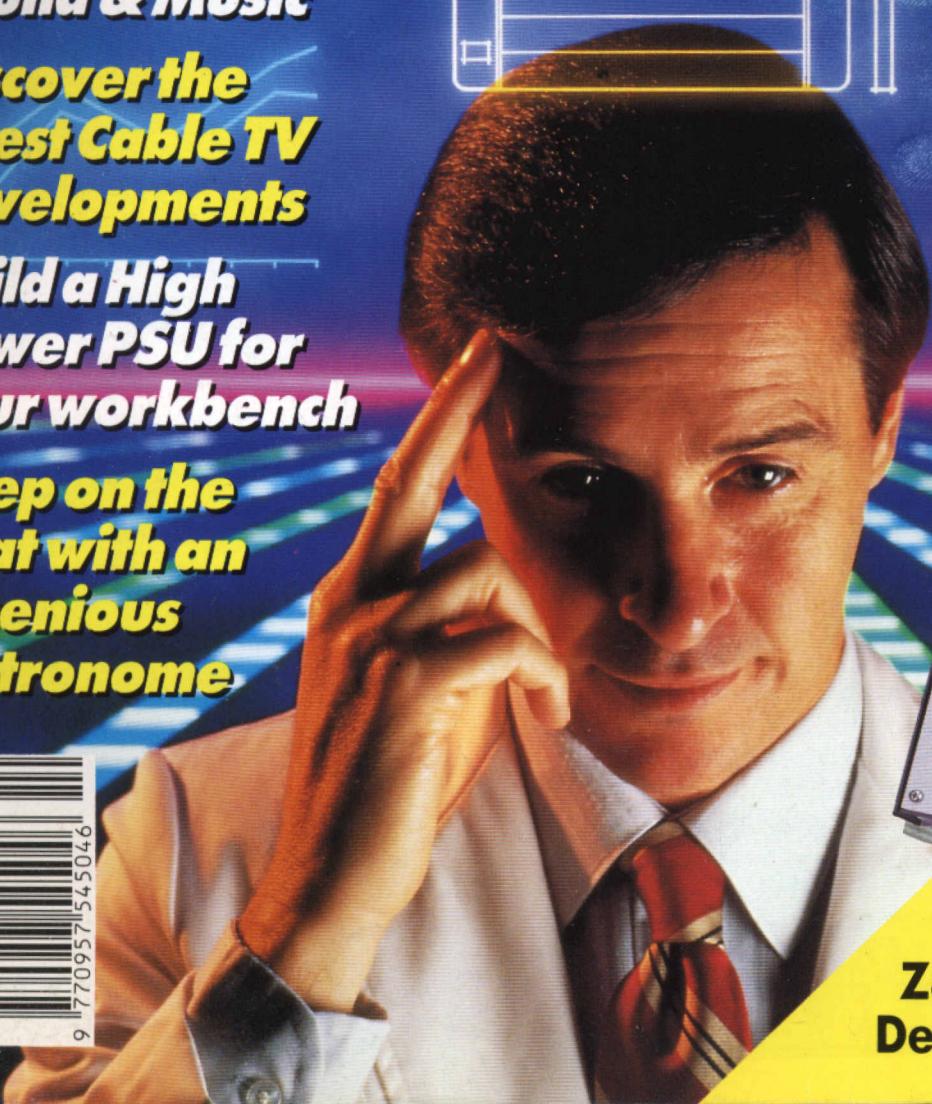
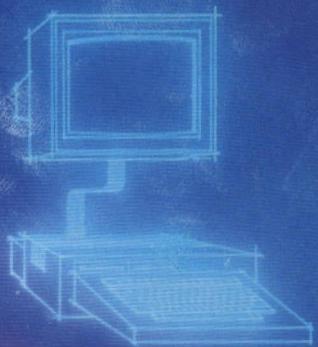
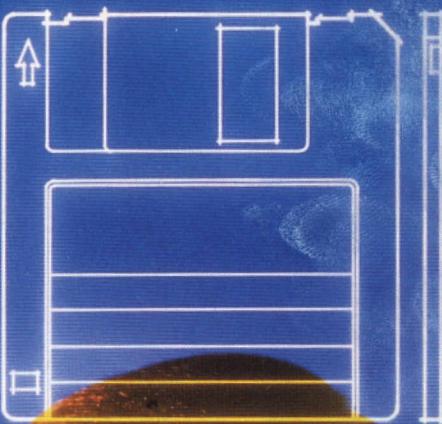
(in this issue)

**Give your PC
the Gift of
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**Discover the
latest Cable TV
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**Build a High
Power PSU for
your workbench**

**Keep on the
beat with an
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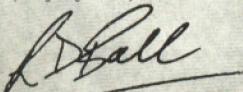


**Build your own
Z80 Microprocessor
Development System!**

EDITORIAL

Hello and welcome to this month's issue of Britain's best selling electronics magazine! In this issue there is a fine collection of projects and features. For the musically inclined there are two quite different projects that will be of interest. The MetroBeat is an unusual variation on the metronome theme, the key difference being that the MetroBeat can be set to follow your tempo, instead of you following it! The MetroBeat also provides a digital display of the number of beats per minute, ideal for scoring and writing music. For the computer user, the PC Sound Card is great for producing a more tuneful output than a standard PC is otherwise capable of! The card can be easily programmed from BASIC and has stereo capability. On the features front, Stephen Waddington joins our team of regular contributors; over the coming months he'll be focusing on new technology in the electronics field. This issue, Stephen takes a closer look at the latest solar cell technology. This issue also sees the launch of the 'Electronics Subscribers' Club, one of the key benefits is a 5% discount on Maplin goods; over the coming months more exclusive special offers will be announced, so watch this space! If you are not already a subscriber then you are really missing out! Firstly, it's actually cheaper than buying 'Electronics' over the counter; secondly, each issue is posted to you free of charge before it's available in the shops! Further information on taking out a subscription can be found on page 14! If you are already a subscriber to 'Electronics' you will find that your 5% discount card is included with this issue!

So until next month, all that remains for me to say is I hope that you enjoy reading this issue as much as the 'team' and I have enjoyed putting it together for you!



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October 1992 Maplin Magazine

PROJECTS

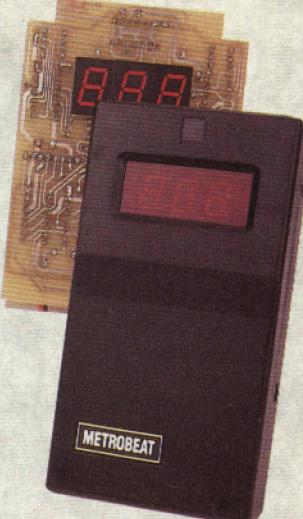
4 3-TONE CHIME

■ Attract attention with this easy-to-build chime!



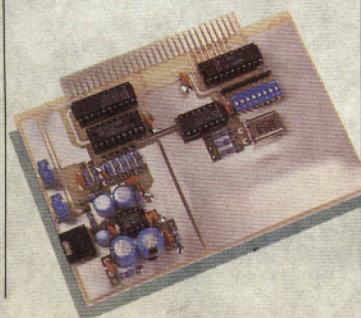
16 METROBEAT

■ Keep right on time with this innovative musicians' project.



24 PC SOUND CARD

■ Are you bored with the feeble bleeps that normally emanate from your PC? If so this project is for you!



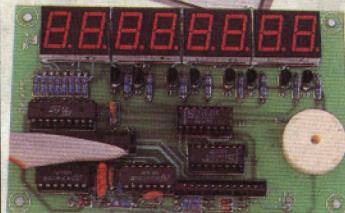
40 10A LABORATORY PSU

■ At last – a decent quality PSU with guts!



56 Z80 DEVELOPMENT SYSTEM

■ Develop your own Z80 control system. This versatile project has both practical and educational uses.



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■ Martin Pipe & Alan Simpson take a look at the current developments in cable TV.



32 PROJECTING AHEAD

■ Ever wondered how an idea for a project ends up in this magazine? This exclusive feature reveals the secrets!



48 CIS PHOTOCELLS

■ Discover all about the new technology set to replace silicon photocells.

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■ Ray Marston reveals the secrets of designing waveform generator circuits!

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Michel Tcherevkooff.

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NEWS Report

Londoners do it Digitally!

One of London's most exclusive locations, the rotating platform of Telecom Tower, recently saw BT bid farewell to an old London friend. The departing companion was the 1930s technology for the Strowger Telephone exchange system.

In a video conference link with DJ Pete Murray, BT Deputy Chairman



Mike Brett received the first call on London's all electronic system. The last exchange to switch (pun intended!) is in Stapleford, Essex. It serves 400 mainly residential customers. The new digital installation now means that the entire London Network benefits from the features of digital exchanges. It also makes London's telecommunications the most advanced of all European Capitals.

The advantages to customers of digital exchanges include itemised billing, call waiting, call barring, call diversion and three way calls. Also now fully possible is Calling Line Identity (CLI). This enables the details and number of the calling party to be known to the recipient of the call. At present CLI is only used in connection with the 999 services. BT have confirmed that the technology is available to provide all digital exchanges with CLI, but unspecified "negotiations with the Regulator" (Oftel) are preventing domestic or business availability of CLI at present. CLI also means that source of nuisance and obscene phone calls is easily identifiable to the authorities.

With BT's investment reported to be £46 per second, the completion of London's digitalisation represents a major achievement. Call set up and connection time is now measured in milliseconds and has a 99.6% success rate. BT has certainly come a long way since the Post Office Tower was London's tallest building.

Compressed HDTV

A Scandinavian group has developed a digital terrestrial High Definition Television (HDTV) system that it claims could be transmitting programs before the end of the decade. Hardware developed in the last twelve months was on display at the recent International Broadcasting Convention held in the Netherlands, with transmissions between a show stand and an outside site.

HD-Divine seeks to overtake Europe's HD-Mac, a 1250-line system which was developed in twelve research laboratories throughout the continent. HD-Mac's main failing is that it relies on distribution by satellite, a point emphasised by the recent demonstration broadcasts from the Olympic games.

In harmony with the European standard, HD-Divine signal maintains the 1250-line, 50Hz criterion. Uncoded, the signal forms 900Mbps, but by using compression and image coding techniques this is reduced to about 24Mbps. As a result, HD-Divine allows narrow UHF TV channels to be used, squeezing the HDTV signal into a bandwidth of 8MHz rather than the usual 12MHz.

Those behind the project are aiming to prove that an inexpensive but advanced HDTV system can be launched by the turn of the century. Such speed would ensure a break against existing Japanese and American projects.

Wharf a Load of Rubbish

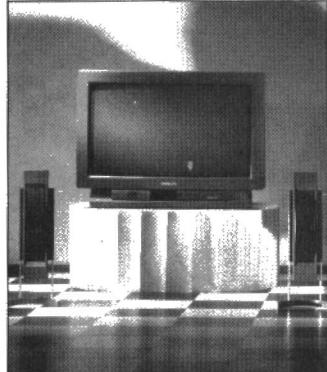
Whilst Europe's tallest building at Canary Wharf stands as a monument to modern building techniques, high tech design and striking appearance, thousands of people are not so impressed by the radio frequency shadow it casts. The building's cladding acts as a highly efficient reflector of radio waves, consequently, television and other radio frequency transmissions are suffering from severe attenuation and/or multi-path distortion. Apparently the planners didn't consider this aspect of the proposal when granting planning permission. Once the problem came to light, it was too late to change the cladding material. TV bosses are said to be furious, it will take a huge capital investment and many years of work to set up relay stations to overcome the problem.

Try Saying it with Your Mouth Full

Germany's Schutzgemeinschaft frallgemeine Kreditsicherung, an association of credit lenders, has put Debris-Systemhaus GmbH, a Leinfelden-Echterdingen-based Daimler-Benz subsidiary, in charge of its IT services.

On Your Marks

There must be something about sport which attracts the developers and marketing teams of HDTV and wide-screen television. First it was Wimbledon where the BBC used High definition TV pictures as a back-up for standard broadcasts - a standards converter turning the picture into normal resolution images. The HDTV pictures were relayed to Seville for display at Expo '92.



Then viewers with wide-screen sets were able to enjoy the Olympic Games, thanks to live 16:9 broadcasts - via satellite, throughout each event. In fact the HDTV momentum is speeding up. Philips, apart from announcing a new wide-screen set - the 28in. 8916, has been supported by news from the world of video. Major video companies Fox, Columbia, Warner, CIC and Palace have all announced an ongoing programme of wide-screen video releases. Already over fifty titles are currently available. Such popular titles as 'Alien', and the 'Back to the Future' and 'Indiana Jones' trilogies are available in letterbox form.

Now Kodak has joined in the wide-screen movement and demonstrated technology which allows films to be shown on HDTV with cinematic quality. The Kodak Telecine method will transfer film shot using 35mm, 16mm or Super 16 formats into either the 1125 or 1250 line standard TV pictures.

Quote Unquote

The president of Thinking Software, Joseph Weintraub, is on record as saying: "Computer programs will eventually move beyond mimicking human conversation and into the realm of thought, but humans should always keep the upper hand. I think it's very important that we always stay close to the electricity supply."

Stop that Car

The latest US anti-carjacking system incorporates some neat features. As the car thief high-jacks your car at knife point, the owner can trigger the car's alarm system with a hand-held remote control 'zapper'. This has a built-in two minute delay factor (by the time it activates the thief will be too far away to remonstrate with the car owner). The system will shut down the car engine, lock the doors, wind up the windows and at the same time, sound an ear-splitting siren from within the car. The arrival of the cops could be relief.

More car news. The DTI has announced the E-Auto project, a super-efficient motor car powered by a petrol or diesel engine designed specifically for maximum mileage - the aim is 200 miles to the gallon - and to minimise environmental impact. Although now only at the planning stage, it should be usable in three years time. The project is one of 102 schemes announced by the 20 EUREKA members involving a total of 107 UK organisations.

Perfectly Converted

WordPerfect Corporation has launched another new product, ConvertPerfect. This easy-to-use, menu driven utility allows document file conversion to and from several different formats, including of course, WordPerfect. ConvertPerfect runs under MS-DOS and allows batch conversion of entire groups of files with a single command. It is much more user-friendly than the file conversion utility supplied with WordPerfect and offers a wider range of file conversions. Electronics - The Maplin Magazine already uses WordPerfect 5.1 to satisfy a wide variety of its wordprocessing requirements. The editorial team in particular have found ConvertPerfect to be extremely useful since outside contributors often use different wordprocessing packages. Further details may be obtained direct from WordPerfect UK, Tel: 0932 850505.

Light Work



Earlier this year a dozen divers converged on the Goitres Vif, in the Chartreuse region of France, to tackle the longest cave system in France. The caves are largely unexplored - partly because of the problem of access. Last year a small group of divers from Britain took up the challenge but it was not until the last day of the expedition that the main cave was reached. The logistics were formidable - each diver having three cylinders and assorted equipment.

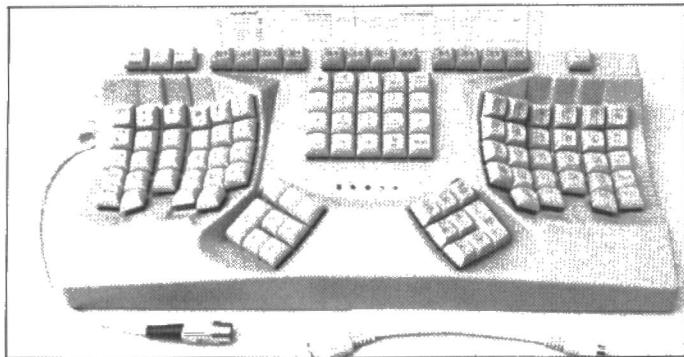
As expedition member Mark Dougherty from Leeds University said: "Divers could spend more time simply carrying equipment, rather than getting on with the more important tasks of exploration and surveying." This year, the diving team has a non-diving support team on hand to help ferry equipment up and down the mountain. The team have also sourced sponsorship of extra equipment to add to the safety margin of the divers.

One of several companies responding to the cave diving expedition appeal was Maplin Electronics Plc. In association with leading battery manufacturer, Uniross, Maplin and Uniross have supplied 48 industrial grade rechargeable C size 2,000mAh industrial grade Ni-Cd cells together with 20 rechargeable AA size 600mAh Ni-Cd cells. In addition Maplin have also provided the team with 4 Ni-Cd battery chargers. The presentation of the equipment took place at the Maplin's central Leeds store.

The Squarial Rides Again

Northern Telecom Europe is providing satellite TV viewers in Germany and other European countries with a new, unobtrusive, flat plate antenna as an alternative to dish based systems. Launched by Technisat, the new antenna is only 47cm square and has a smooth flat surface with its LNB placed out of sight at the rear of the unit. Details, Tel: 0628-812190.

British Solution to RSI



Manufacturers of the Maltron keyboard continue to combat the problems of RSI. Their keyboards, made to order, cost between £200 and £400. Customers are predominately disabled or suffer from RSI.

A split design, moulded in a three dimensional semi-circular bowl shape, the Maltron comes as something of a culture-shock to the uninitiated. Its functions are diverse, both left and right handed boards cater for disabled people, whilst a two handed version can replace the Qwerty keyboard. The Maltron can be configured to suit any keyboard layout, including QWERTY,

although most new users opt for a specially designed ergonomic format.

The cost of retraining operators has always been a predominant reason for maintaining the QWERTY dinosaur. Whatever format is selected, the Maltron can be mastered very quickly. Operators who have made the change adapt and return to usual speed after a period of hours.

Recommendations come from numerous sources, not least twenty or so RSI sufferers who having been crippled by the standard keyboard, who, after switching to the Maltron found their problems eradicated.

Diary Dates

Until 31 October. 'Friendly Invasion', RAF Museum, Hendon. Tel: 081-205 9191.

Until January '93. The Irn-Bru Pop Video Exhibition. MOMI, South Bank, London. Tel: 071-815 1339.

13 September. Farnborough Air Show. Society of British Aerospace Companies. Tel: 071-839 3231.

22 to 24 September. Image Processing Exhibition, Birmingham. Tel: 081-868 4466.

22 to 24 September. COMEX '92, Wembley, Middlesex. Tel: 081-778 3343.

23 September. Interactive Multi-Media, Loughborough University. IEE, Tel: 071-240 1871.

29 September to 1 October. Euro Teleconference '92, Wembley, Middlesex. Tel: 0234-212988.

5 to 9 October. SICOB (business equipment), Paris. Tel: 071-221 3660.

6 to 8 October. VOICE '92 (Computer telephony and voice automation), Olympia, London. Tel: 081-877 9007.

6 to 8 October. Exclusively Tools, Wembley, London. Tel: 081-868 4466.

20 October to 1 November. British International Motor Show, NEC, Birmingham, Tel 0483-222888.

28 to 31 October. Apple Expo '92/ The MAC-User Show, Olympia, London. Tel: 071-404 4844.

19 to 22 November. Computer Shopper Show, Olympia, London. Tel: 071-373 8141.

Please send details of events for inclusion in 'Diary Dates' to: The Editor, 'Electronics - The Maplin Magazine', P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Sugar Sweetens the Notebook Market

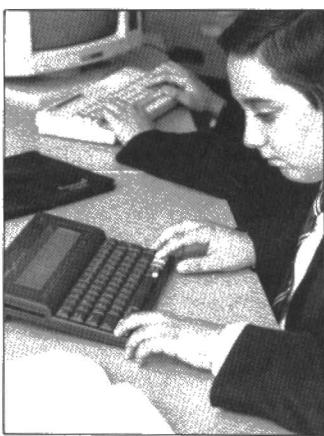
So confident is Alan Sugar, the ebullient chairman of Amstrad that the new NC100 Notepad, a £199.99 VAT inclusive A4 sized slimline portable computer, is the "world's easiest to use computer" that he has issued a consumer challenge. "If you can't use an Amstrad Notepad in just 5 minutes, you'll get your money back". Amstrad may be overestimating the marketplace - some individuals find even operating an electric toaster something of a challenge (try plugging it in Alan! - Ed.).

The Amstrad notebook has been designed to appeal primarily to the 80% of the population which does not own or cannot use a computer. It will also, says Amstrad, prove invaluable to business people, students, journalists and many others who need immediate access to an inexpensive, easy to use but thoroughly serious computer.

The Amstrad Notepad screen display is an 80 characters x 8 line super-twist LCD. Fitted with four standard AA size batteries for over 40 hours use, or from the mains power supply, the 1kg unit runs at 6MHz with a Z80 CPU and 64KB battery backed-up static onboard user memory. The Notepad is fitted with a standard PCMCIA card slot so that extra memory can be added with industry standard S-RAM memory cards (64KB to 1MB). All software is in ROM, giving immediate use without the need for further loading. The new Notepad is the first in the line of products incorporating Sugar's back to basics strategy. A similar design approach was taken with Amstrad word processors.

Radio Science

That well-known radio station, GB2SM, based at London's Science Museum has had an upgrade. Racal Radio has presented the Museum with an RA3701 HF receiver (the 6th Racal Radio receiver to be donated to the Museum since 1955). The new receiver is a high performance HF receiver covering the frequency range 15kHz and its construction enables the addition of further optional modules. The easy to use system contains a comprehensive built-in test equipment capability. It will be used by the Museum's GB2SM station for receiving facsimile and radio teletype transmissions, as well as for two-way communications. GB2SM was the first working radio station of its kind set up anywhere in the world to illustrate all aspects of radio communications through a series of running demonstrations. It has, over the years, communicated with amateur radio enthusiasts from over 250 countries.



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STOP PRESS ... STOP PRESS...STOP PRESS...

Going Digital

With the new boss now installed at Ofcom - the telecoms regulatory body - it was on the cards that the threatened change to the UK telephone numbering system would be postponed, or even cancelled. The evil day has now been postponed until 1995 - a year later than planned. The plan to add an extra digit '1' after the initial '0' in UK STD telephone numbers has been openly challenged by Mercury. Also on the opposing front is comms industry authority Vernon del Espino of Telecommunications Services, who states that a simple redeployment of existing unused numbers could resolve the matter. If it could, a considerable amount of confusion, not to mention expenses, would be saved.

display emits negligible levels of radiation - lower than that of a typical light bulb. Reducing eye strain and fatigue, it is set to be a hit with secretaries, journalists, programmers and just about anyone who uses a computer for long periods.

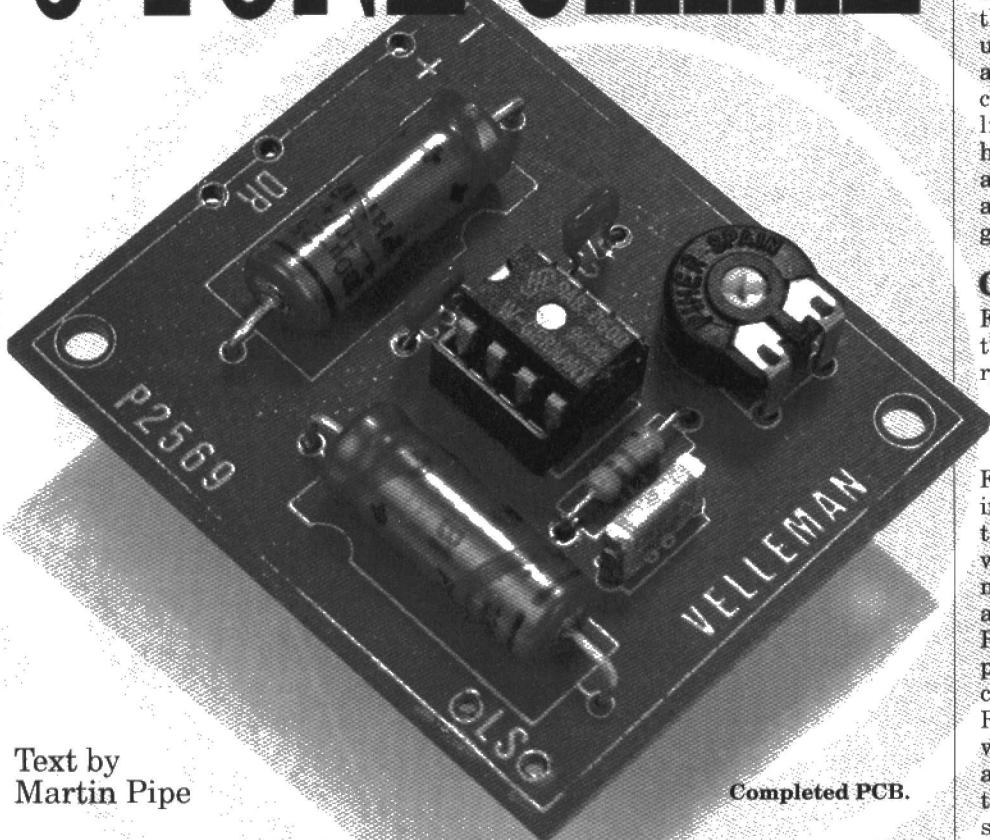


The LCM64, which was designed in Britain, uses Citizen's own high performance, backlit 640 x 480 VGA LCD incorporating RCF (retardation control film) and STN (super twist nematic) technologies. The monitor is suitable for both text and graphics and can be connected to an IBM PC compatible computer by means of a special plug-in display controller card. The RRP is £699 (plus VAT), further details can be obtained from Citizen Europe Ltd., Tel: 0753-584111.

Crystal Clear

Citizen is set to lead the fast growing market for high quality LCD monitors with the launch of their LCM64. The new compact monochrome monitor has been designed to be a space saving alternative to conventional CRT monitors. The flicker free, non-glare

333 TONE CHIME



Text by
Martin Pipe

Completed PCB.

FEATURES

- * Extremely low standby current
- * Drives 8Ω loudspeakers
- * Adjustable pitch

APPLICATIONS

- * Door chime
- * Public address call systems
- * Games

Specifications

Voltage required: 7 to 12V DC
Quiescent current: less than 1µA
Output impedance: 8Ω
Output power: typically 0.4W

Introduction

This low-cost kit is designed for use as an audio signalling device and is capable of driving an 8Ω loudspeaker. When the unit is triggered, it produces a complex set of three-tone follow-up signals, each tone being half of the others harmonic frequency. This unusual sound has been found to attract maximum attention when preceding announcements made on public address systems – such systems have been used at railway stations and airports for many years. Other applications include door chimes, games, toys and sound effects.

Circuit Description

Figure 1 shows the circuit diagram for this simple circuit. Most of the circuitry is contained within IC1, a SAB 0600 integrated circuit, which requires only a few additional components to operate. IC1 (shown in Figure 2) is a compact device containing three logic-controlled tone generators, synchronised to a master clock, which are triggered when pin 1 is momentarily held at the supply voltage. The clock frequency is set by RV1/R1 and C5; if the time constant produced by these components is changed (by altering the value of RV1), the pitch/timing of the chime will vary. The three tone generators are in fact three 4-bit D/A converters; the tones generated by them are summed together via three internal resistors before being passed to the audio amplifier. The characteristic sound is determined by the delay time of each of the three discrete tones; additionally C4, in conjunction with a resistor internal to the IC, forms a high frequency filter that gets rid of the unwanted harmonics, producing a less 'hard' and more melodious output. C2 is used to block the DC offset that is present on pin 3, the IC's AF output. Coupling capacitor C3 is present to ensure that the IC is not triggered by interference or cross-talk sources. The final component is C1, used for power supply decoupling.

PCB Assembly

The information required to help you with the assembly can be found in the construction leaflet supplied with the kit. Additional information on soldering and general assembly techniques, should you need it, can be found in the Constructors' Guide (Order Code XH79L).

The printed circuit board (PCB) is a single-sided type, with a legend to assist you in correctly positioning each item. Removal of an incorrectly fitted component can be fairly difficult

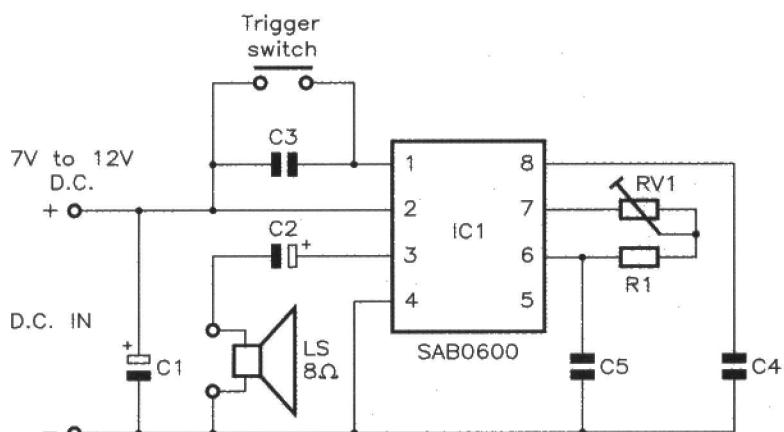


Figure 1. Circuit diagram.

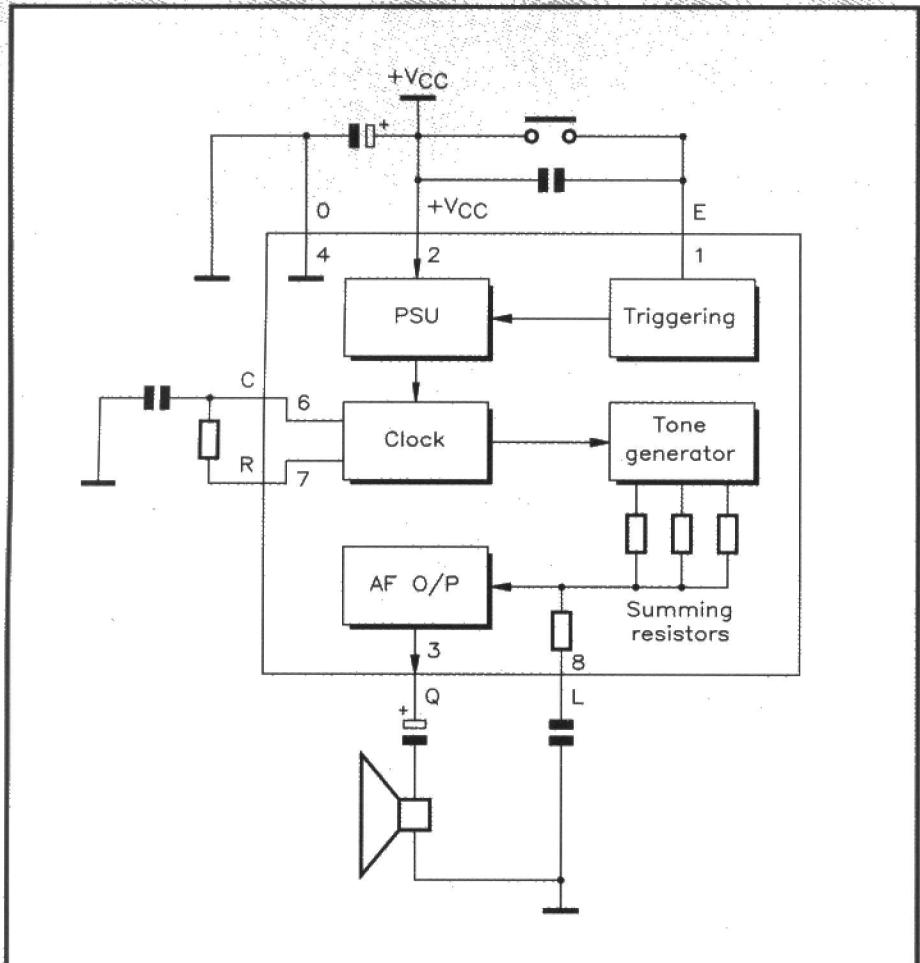


Figure 2. Block diagram of SAB 0600, and associated components.

without damaging it, or the PCB, in some way, so please double-check each component type, value and polarity (where appropriate), before soldering! Start construction with the resistor/preset first, followed by the capacitors. When fitting the electrolytic capacitors into place, please

ensure the correct polarity before soldering it in. The same applies to the IC socket; this has a notch on it, which should correspond to the one shown on the board legend. Finally, IC1 should be fitted into its socket – the correct way round!

This completes the assembly of the

PCB (see Photo 1), and you should now check your work very carefully, making sure that all of the solder joints are sound. It is also very important to ascertain that the solder side of the circuit board does not have any trimmed component leads protruding by more than 2mm, as a short-circuit could otherwise result.

Testing and Use

Figure 3 shows you how to wire up the trigger switch, power supply and 8Ω loudspeaker to the completed board. For testing purposes, a PP3 battery will be sufficient. If the circuit doesn't work, check all components for correct installation on the PCB.

The unit can also be connected to an external audio amplifier, or mixer, by substituting the loudspeaker with two resistors (which constitute an impedance/level matcher) as shown in Figure 4. With the values shown, an output of approximately 1V is obtained when the unit is connected to an amplifier with an input impedance of 10kΩ.

The unit requires a power supply of between 7 and 12V DC to operate as intended. Because the current consumption is low, an alkaline PP3 battery is more than adequate, and will last for a long time. Such an arrangement will be ideal if the unit is to be used as a door chime. If replacing an old doorbell, your existing bell transformer unit can be used – but *only* if it produces a DC output within the above voltage constraints. There are many different suitable power supplies available, but in the end your

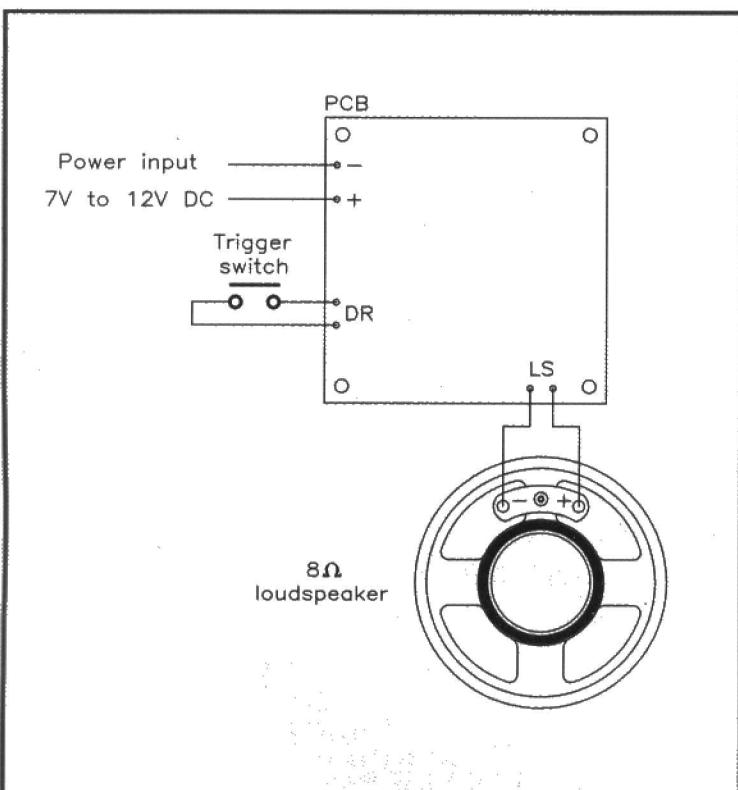


Figure 3. Wiring diagram.

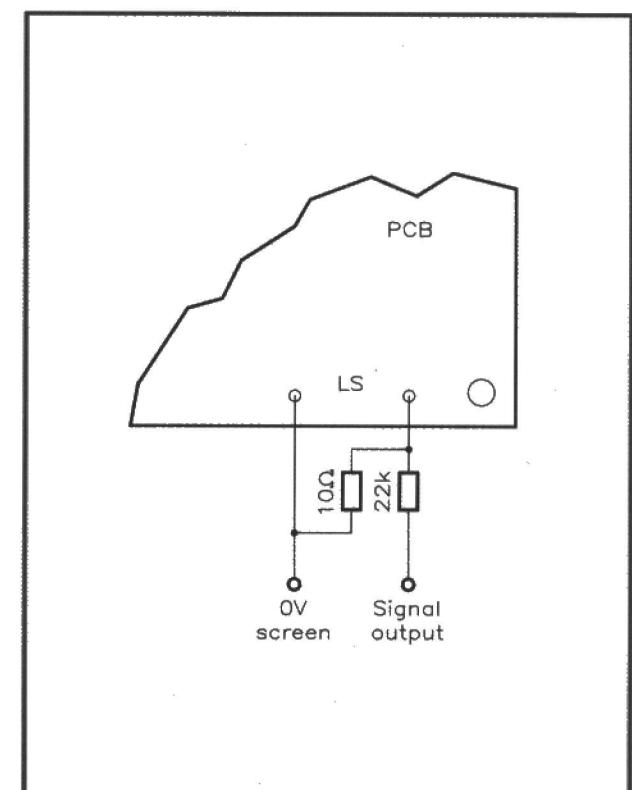


Figure 4. Optional amplifier connections.

choice must depend on the application for which the circuit is destined.

The same applies to the trigger switch used, which need only be a simple 'push-to-make' switch. If the unit is to be used as a door chime, for example, then a bell-push type switch will be required (Order Code FS17T). Of course, if the 3-Tone Chime is to replace your old doorbell, the existing bell-push can be used!

The kit is supplied in a clear plastic case, which could be used to house the project. If a loudspeaker is to be built into this case, holes should be drilled in it to 'let the sound out'. Because it is moulded from clear plastic, you can paint it to your own design. Other suitable cases are available, see the current Maplin Catalogue for details.

Door chime apart, this little kit has several other uses. In addition to being used in games (such as quizzes, whenever a 'correct' answer is made), the 3-Tone Chime could be hooked up to a PA amplifier, using the modifica-

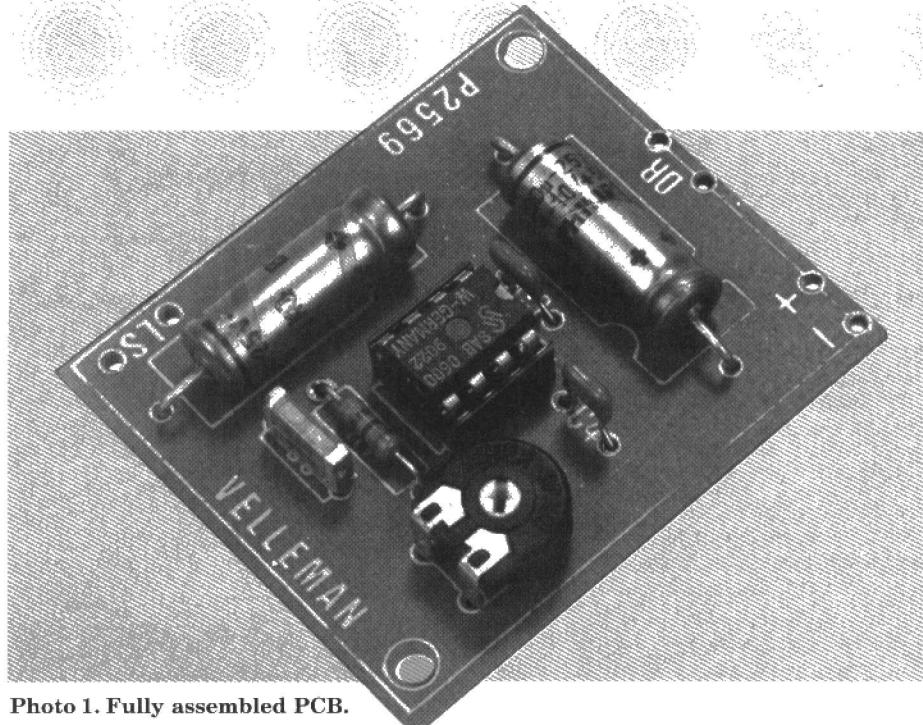


Photo 1. Fully assembled PCB.

tion already outlined; it could then be used to signal announcements at special events, including rallies, boot sales and church fetes. Because of its

similarity to the chimes used in public places, it could also be used as a sound effect in a play, home video production or radio programme, for example.

3-TONE CHIME PARTS LIST

RESISTORS

R1	4k7	1
RV1	4k7	1

CAPACITORS

C1, C2	100µF 25V Axial Electrolytic	2
C3, C4	100nF Resin-dipped Ceramic	2
C5	4n7 Polyester Layer	1

SEMICONDUCTORS

IC1	SAB 0600	1
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MISCELLANEOUS

PCB	1
8-pin DIL Socket	1
Presentation Case	1
Instruction Leaflet	1

OPTIONAL (Not in Kit)

8Ω Miniature Speaker	1	(YW53H)
Push-to-make Switch	1	(FH59P)
or Bell-Push Switch	1	(FS17T)
Battery Clip Type PP3	1	(HF28F)
Alkaline PP3	1	(FK67X)
Black Hook-up Wire	As Req.	(BL00A)
Bell Twin Wire	As Req.	(XR39N)

The Maplin 'Get-you-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available in kit form only.

Order As VE88V (3-Tone Chime Kit) Price £9.95.

Please note: Some parts, which are specific to this project (e.g. IC1, PCB) are not available separately.

COMPETITION WINNERS

'April Fool' Magazine Subscription Competition

The correct answer to the April Fool Subscription Competition, which appeared in the May issue of 'Electronics', was as follows:

A. The 'Clearbeer' electronic beer line cleaner, is the only item that really exists!

This left:

The three supposed new products described, which are not bona fide, genuine and true items are:

B. The Fusilier water fusion powered car.

C. The 'Dreamer' brain enhancer, improves your IQ while you sleep.

D. The VTDR (Video Time Delay Receiver), supposed to enable you to record TV programmes up to 72 hours after transmission, due to radio waves being trapped between ionospheric layers and bouncing around for a while before escaping again – nonsense of course.

In addition to guessing the three nonsense items, entrants

were asked which of the four would be really useful and a marketable product for Maplin if it were possible for them to be made. The first five winners to be drawn out of the moth-eaten Editor's hat (the hat, not the Editor! – Ed.), and their suggestions are listed below. They each win a year's subscription to 'Electronics – The Maplin Magazine'.

M. B. Housley, Milton Keynes, Buckinghamshire. "I think that the atomic water power is excellent; smaller units could be built replacing petrol driven AC portable generators for power tools, camping, emergencies, etc."

John Crowhurst, St. Albans, Hertfordshire. "I think Maplin should sell the 'Clearbeer' Unit because, in addition to its original purpose, the same concept could be used for domestic water pipes, particularly in hard water areas, in order to prevent lime scale forming and seizing up of stop-cocks, etc."

Philip Greenhouse, Birmingham. "Maplin should sell the 'Dreamer' brain enhancer because then I could buy one, as I always wanted a big head! And then I could make more money to buy more Maplin kits!"

Mr. J. Lawson-Reay, Llandudno, Gwynedd (North Wales). "If Maplin stocked the VTDR I'd buy one in a trice. Imagine being able to watch programmes you didn't know were on until five minutes after they'd finished, or you'd missed because even though you set the recorder properly, they were transmitted late!" (We know the feeling – Ed.)

Mr A Nicolaou, Gravesend, Kent. "I suggest the 'Clearbeer'. While a number of commercial designs exist, it might be used to deal with the accumulation of mineral salts especially calcium compounds which solidify, water blocking pipes, filters etc."

Alton Towers Competition

The questions and correct answers to the Alton Towers Competition, which appeared in the July issue of 'Electronics', were as follows:

1. What is the approximate mileage from London to Alton?

b) 200 miles.

2. What term best describes the Park?

a) Magical Kingdom.

3. The Corkscrew is...

c) The name given to a popular ride at the park.

4. Who was Charles Talbot?

b) The 15th Earl of Shrewsbury and founder of the park.

The first lucky winner to be drawn of the hat was Mr J. E. Davies, Macclesfield, Cheshire, who wins an entry ticket for four people to visit Alton Towers free of charge. The two runners-up are, Mrs M. J. Brown, Bognor Regis, West Sussex and Mr G. E. Roberts, Breaston, Derby, who each win an entry ticket for two people to visit Alton Towers free of charge.

FROM UP ABOVE

Satellite

by Alan Simpson and Martin Pipe

At last it seems that cable television is emerging from its conduits and pipelines. Or, as the industry publication 'Cabling World' put it; "All that road digging is at last paying dividends!"

The cable TV industry expects to pass some 2.2m homes nationally by the end of the year, almost doubling the present levels. In fact the Cable TV Association is forecasting that, come early 1993, there will be at least 500,000 cable TV subscribers and, perhaps even more dramatically, over 100,000 subscribers taking advantage of the associated telephony services.

Even at the cable-laying end, Cable London, one of the 135 franchises granted, report being run off their feet, following their recent high profile marketing. Choice and competition (but why no mention of quality?), are the selling points of the cable TV service suppliers. As they point out, how often have you switched on your terrestrial TV late at night, to be confronted with four channels showing darts, snooker, an obscure Italian opera and a Third World feminist discussion group? Of course, some may argue that at such times most people are in bed, minority groups have a right to off-peak broadcast coverage, and that shift-workers are only a small fraction of the population! However, the key point being made by the cable companies is one of choice.

Compare this frugal fare, (unless you happen to be a keen opera, darts or snooker fan) with the offerings of the cable companies. With over twenty channels available, as well as the globally popular CNN news programme (now available on Astra 1B1), the cable TV package is hard to resist. Many argue that most of these channels are watchable free (and indeed with stereo sound) with a suitable motorised satellite system – or indeed a simple Astra receiving system (for Sky, etc). But thanks to ridiculous constraints imposed by the Government and local planning departments on the siting and size of satellite dishes (so much for the 'freedom to choose' – even in your own back garden!), this option is denied in certain areas – for example, council

flats in some inner city areas. In southern areas of the UK, a 60cm dish is the largest that can be erected without planning permission; a dish of this size will simply not provide enough gain for the noise-free reception of satellites other than Astra (and possibly the stronger Eutelsats). For these people, and indeed those who do not want a dish on the side (or indeed front) of their house, cable TV is the only way of bringing a huge variety of TV entertainment into the home – if you have it in your area.

Let the (Ratings) Battle Commence!

Cable and satellite channels are increasing their share of viewing in cabled homes, according to the latest audience research undertaken by the

controlling authority, the Government-appointed Independent Television Commission (ITC) – better known to the public as the body responsible for selling off ITV franchises to the highest bidder. According to their survey, the weekly share of total viewing taken by cable and satellite channels in suitably-equipped homes is close to 50% – and that survey was taken before the recent extensive coverage of the Cricket and Rugby World Cup contests, which were broadcast exclusively on Sky (so much for the deregulation of broadcasting providing a better choice for everyone!) Even more dramatically, the BSkyB satellite movie channels are now close to taking 25% of all viewing in cabled homes.

Upwardly Mobile

Further ITC research shows that more



OR DOWN BELOW OR CABLE?

cabled homes (nearly 20%) are now taking an extra cable connection to serve a second television set. This has an effect on the viewing of the themed channels such as Sky Sports, the 'Comedy' Channel, MTV, and Sky Movies Plus/The Movie Channel. When it came to the time-shifting of movie programmes in broadband cable homes, the survey revealed that Sky Movies was, predictably, ahead of both BBC and ITV.

The latest available figures published by the ITC reveal three interesting facts. Firstly, the number of homes connected to broadband cable now exceeds a quarter of a million, and this figure is increasing by over 10,000 a month. Secondly, the average take-up rate has now reached 20% - 2% above what it was a year ago. Thirdly, for the first time, subscribers to the new broad-

band franchises exceed those to the older satellite master antenna TV (SMATV) based systems, and now comprise the majority of cable viewers in the UK.

As mentioned in January's 'News Report', the DTI, in an attempt to speed up cabling operations, have been urging the cable franchise holders to 'get laying or get out'. With most of the present franchise operators being huge US communications companies, it is likely that only a couple of existing holders will fail to heed the financial and action warnings. Certainly, no one can point a finger at Cable London, who expect to achieve a 35% penetration of their franchise area (which comprises much of North London) within the next 15 months. With an estimated 75% of the entire UK being cabled within the next few years, it seems that the cable

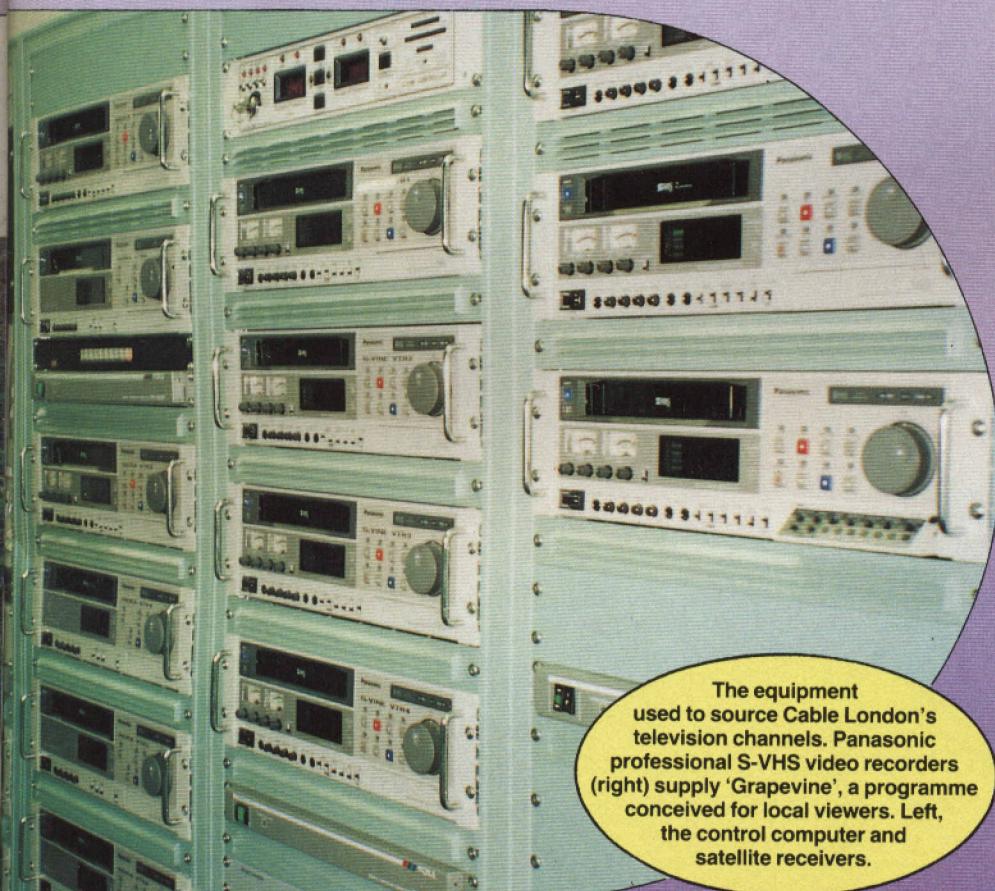
operators have got the message!

Laying the Foundations

Until the early 1980s, report the ITC, the UK had only very limited cable networks. These so-called 'narrowband' systems simply relayed broadcast television (BBC1, BBC2, ITV, Channel 4) services to areas with poor quality broadcast reception. Later set-ups (for example Cable London's original 'Cabletime' system) offered alternative programmes - such as Sky Channel (the forerunner to today's much loved Sky One!). Indeed, domestic satellite TV systems were originally conceived in the early Eighties to (illegally?) 'eavesdrop' on such broadcasters, many of which started out as cable programme providers.

To all intents and purposes, satellite and cable systems are the only options available to new UK broadcasters. As the ITC make clear, broadcasting frequencies for terrestrial transmitters are a strictly rationed (marketable?) resource. ITV provides, theoretically at least, only one channel throughout the whole of the UK, with only one licensee operating in any given region. The terrestrial frequencies left over are sufficient to allow a nation-wide Channel 4 (S4C in Wales), and a future fifth channel apparently only capable of reaching some 74% of the population.

Cable and satellite television do not suffer the same constraints. The typical broadband cable system is currently being designed with a bandwidth of 550MHz, allowing capacity for about 45 television channels. Some systems are being built with 860MHz bandwidth, which could allow up to 70 channels, while technology is being introduced for 1GHz systems. Furthermore, the authority suggest that there have already been trials of digital compression techniques on UK cable systems, which may permit up to eight channels to be transmitted in a space previously occupied by one. What is not discussed, however, is any effect that such compression may have on the quality of the television picture itself! Such interests seem to be secondary to the making of money; the 'unbreakable' Videocrypt system adopted by Sky is definitely



The equipment used to source Cable London's television channels. Panasonic professional S-VHS video recorders (right) supply 'Grapevine', a programme conceived for local viewers. Left, the control computer and satellite receivers.

very secure – but at the cost of poor picture quality. A lower transmitted bandwidth would certainly save cable service providers a great deal of money in the long term, but would it provide benefits to the customer (lower charges, etc.)? Certainly, the picture quality would be worse, but this has not stopped Sky viewers from spending nearly £200 per year for its two movie channels.

Some might argue that a smaller bandwidth-per-channel may be essential – to accommodate the ever-increasing number of programme providers. After all, the number of communications satellites is increasing all the time and, because highly directional dish antennae are required for receiving the low-powered signals, the same frequencies – from the large range available for telecommunications use – can be used from different orbital positions. Many of the transponders on such satellites are leased to television companies to disseminate their programming over a far wider area – eventual distribution often being achieved via cable systems. This includes a large number of state broadcasters who would rather do this than spend a fortune on relay stations for their most distant regions. However, sensible collocation of satellites is essential; witness the recent Eutelsat IIIF/Astra saga. These two satellites, being very close together in terms of orbital position (16° and 19.2° east, respectively), share common frequencies which may interfere with each other – especially when bearing in mind the small 60cm dishes used with such high-powered ‘birds’. Such dishes, millions of which have been installed in the UK for receiving Sky (from Astra), tend to have a relatively wide beamwidth – which might collect some of the signal from the unwanted satellite (particularly if the dish in question has not been correctly installed!). However, the large (often 2 metres in diameter) dishes used at the head-ends of cable stations have a narrow beamwidth – and their alignment is regularly checked. Another brownie point to the cable companies!

Interference or no interference, the list of satellite television channels available over Europe exceeds 100 (About a third are scrambled, though, and decoders for most of these are not available (legally) to UK cable companies and satellite enthusiasts. The scrambling phenomenon was discussed in April's News Report, if you're interested). However, as the ITC comment, the number of television channels available to cable viewers is much more likely to be what the market will bear, rather than what technology will allow.

Getting the Message

A cable network is a means of distributing telecommunications signals to customers throughout a defined area. The network carries both television and (increasingly) telephony, and gives users access to a full range of services via the

one link into an integrated network. At its head-end, Cable London receives the signals from a variety of satellites, including Astra, Intelsat and Eutelsat birds. Some systems also carry local programmes, and indeed normal terrestrial programmes (often with a couple of non-local ITV regions thrown in for good measure). Also contained at this technical centre is the equipment necessary for providing programmes delivered in the form of video tapes. The head-end is also the centre for all of the cable company's telecommunications signals, with a link into the national telephone networks (usually Mercury Communications' digital network) and the control equipment for the telephone lines.

Television and telecommunications signals, received and processed at the head-end, are sent down the cable network on fibre optic and copper cables, via amplifiers which serve to boost the signals where necessary. Each individual customer can then be connected into the network to receive television services and use the national telephone network. The broadband system used by Cable London was developed by Scientific Atlanta.

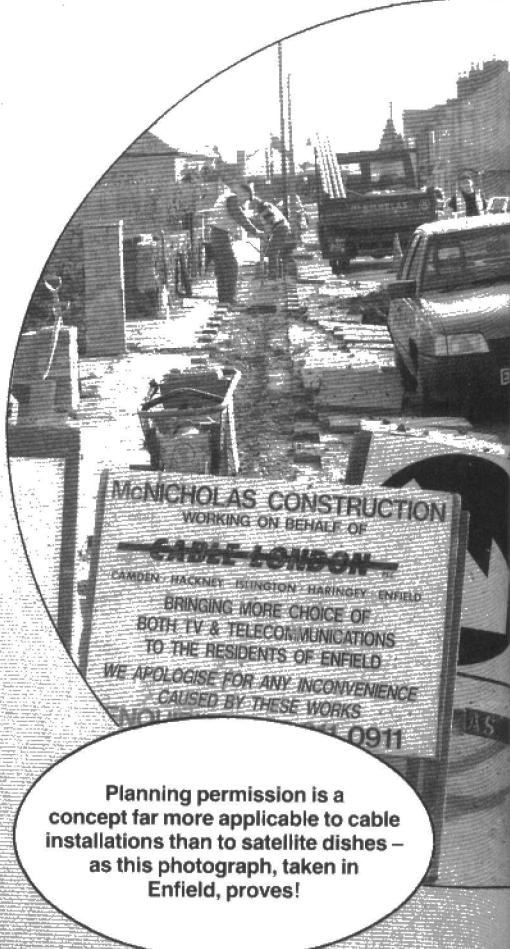
For most of the Cable London network, ‘tree-and-bush’ technology is used as the basis for the network. In this type of system, the signals are carried throughout the whole network, passing into every connected home and business. The system is divided up into a number of ‘nodes’, each node serving up to 4,000 customers. Signals are distributed from the control centre to the nodes via optical fibres; final routing to customers is by means of copper cables. Each customer receives the service by ‘tapping into’ the trunk cable and drawing off the signals they require. Signals from one cable duct are connected into the subscriber's home or office, and are then linked up to the television set (and telephone), via an interface box. In this way, one connection gives subscribers all the television channels they want, and an alternative telephone service. In addition to these, Cable London provides a VHF ‘cable radio’ connection; this enables BBC and ILR stations to be received on a hi-fi tuner with very good signal strength. In addition, the stereo soundtracks of the most popular satellite channels (MTV, Sky Movies+ and the Movie Channel) are re-modulated onto VHF cable radio, a normal stereo tuner being used to recover them. In addition, the three TV channels themselves are re-modulated with NICAM stereo sound; this can be retrieved by a suitably-equipped TV or VCR. Stereo sound enhances enjoyment of films (particularly when a Dolby surround sound system is used), and is essential for MTV!

What You (Don't) Get Is What You See

Cable television customers select and subscribe to a package of channels. Customer access to the correct selec-

tion of channels is controlled by a central computer system and by a set-top cable converter unit that is connected to the television. This unit has its own remote control; this (rather than the TV's remote control) is used to change channel. This piece of equipment is equivalent, as far as the viewer is concerned, to the ‘indoor unit’ used with satellite TV installations. Both ensure that customers receive the channels they have chosen and are entitled to receive.

Any number of TV sets in the house can be connected, as can the VCR. Unfortunately, terrestrial programmes apart (by virtue of a ‘bypass’ facility), you are limited to the one



Planning permission is a concept far more applicable to cable installations than to satellite dishes – as this photograph, taken in Enfield, proves!

programme coming down from the set-top converter at that time – i.e. you cannot watch different cable programmes on different sets, or record one cable programme whilst watching another. The only way out would be to rent a converter for each set – potentially a prohibitively expensive state of affairs! Cable London, however, are offering a connection to a second set for an additional £4 per month – a very reasonable state of affairs.

A similar complication reduces the flexibility of satellite TV systems. Watching one satellite programme while taping another poses problems; another (second-hand?) satellite receiver (and another dish, dual LNB/OMT, or similar arrangement) are required. This would be cheaper (certainly in the long-term) than a second cable connection. Some enterprising manufacturers, however, plan to intro-

A cross-section of the televisual choice available to cable (and satellite) viewers. This double page spread is reproduced from Cable Guide, courtesy of Cable Guide Limited. (Acknowledgments are due to Colin Clayton of Cable Guide Limited).

duce indoor units that incorporate two receivers. Even with such an arrangement, receiving Sky's two film channels independently would require you to subscribe twice (nearly £400 per year!). This is plainly an absurd restriction in itself, and Sky should do something about it (such as a reduced rate second subscription), other than continually repeating their films!

As with Sky's subscription services, Cable London customers need only call a Customer Services Department if they wish to change their package of channels, and a central computer system will make the alteration.

The cable laying itself, while not perhaps high technology, is a high problem area for the contractors – particularly in built-up areas like London. Each has to work with local councils who operate different rules. Certain councils leave it to the cable-laying contractors to lay and reinstate the roadways or pavements, while others prefer to do the reinstatement themselves. Normally the cable is laid at a depth of six feet, but getting there is often an operation fraught with hazards! All too often, no-one knows what may already be buried under the pavements – even the utilities such as water, electricity, phone and gas are often uncertain. So much for the council planning departments maintaining adequate records!

A Better Choice?

But what exactly can the viewer expect

when the cable does get through? As Cable London put it, "we offer our customers more of the sort of programming people like - more sports, more films, more news, more channels broadcasting more of the time." "Our customers", says Alison Pugh, marketing manager, "may be families, single people, youngsters, the elderly, students, people working from home - in fact, anyone in our franchise area who wants more of the programmes they like, at times which suit them".

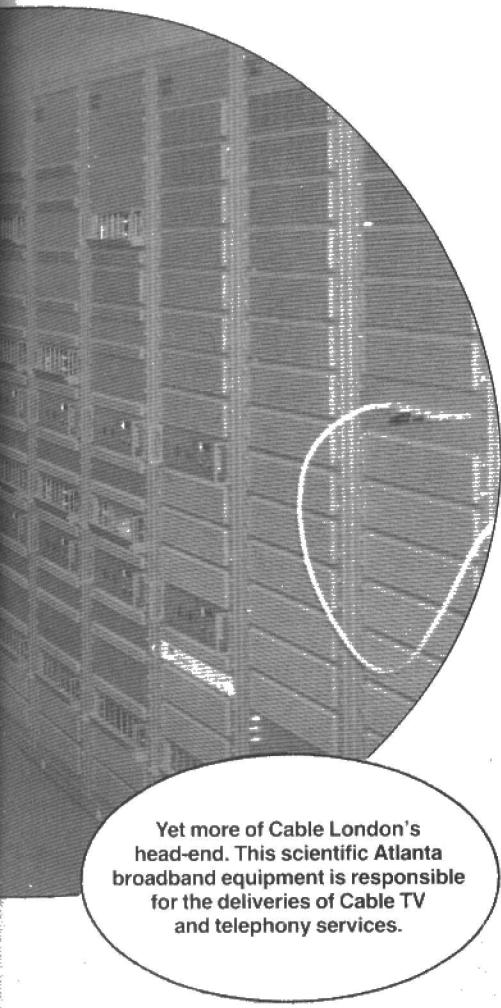
Cable London advocates 'viewing for all', offering such channels as Sky One, BBC1, Discovery, Lifestyle, Children's Channel, ITV, Superchannel, Channel 4, BBC2, and 'Grapevine', a local channel. For movie buffs there is Bravo, Sky Movies, The Movie Channel and HVC, while sports fans are catered for with Screensport, Sky Sports and Eurosport. You can keep in touch with the world via CNN or Sky News, or relax with MTV and Superchannel. Foreign language channels are available in French, German, Greek, Italian, Indian and Afro-Caribbean languages, with Arabic coming on-stream soon.

A local channel, however, is where cable TV really comes into its own. Renting satellite transponders is very costly, and local programmes are only going to be of interest to the targeted region anyway. Cable London's 'Grapevine' carries listings, features and information on local events and community news, as well as locally produced films. Before long, the company will be in-

cluding educational programming for schools, colleges and those studying at home. Cable London have no studio of their own, preferring to rent suitable accommodation. In addition, they train local enthusiasts on camera operation and lighting techniques - apart from saving money in the long-term, it provides much interest for those involved. In fact, the ITC report over fifty different channels on cable to choose from - and that number is likely to increase over the next year or so. This is due in part to the satellite services, such as BSkyB, and the growth of interest in tape delivered programming targeted exclusively at cable operators.

Among the channels highlighted by the ITC are Bravo (a 24-hour service of classic movies), Cable Jukebox (popular music videos), The Discovery Channel (documentary programmes), and Lifestyle (the only European TV channel that is dedicated to women). This last channel presumably compensates for the provision of The Home Video Channel, which shows 'adult' films.

Let us hope, however, that an increased number of services does not result in a reduction of the overall quality, as it does in many other countries (e.g. the USA) where this has been allowed to happen. For after all, many more companies will be fighting ('competing' in the Government's language) for an ever-diminishing slice of ratings, and consequently the advertising/sponsorship cake - the result



Yet more of Cable London's head-end. This scientific Atlanta broadband equipment is responsible for the deliveries of Cable TV and telephony services.

being less money for programme budgets. For the new ITV franchises, the situation is compounded since a great deal of their funds will end up in the Treasury's coffers – and consequently less will be available for quality programming! The situation in the USA, where cable is very popular, is particularly interesting, since its land mass/population is many times that of the UK. Despite this potentially large viewer-per-channel ratio, comparing the quality of American TV with the home-grown output of our ITV, Channel 4 and BBC networks still raises a derisory laugh from many a box-watcher! The question being posed by many industry pundits at the moment is simply whether we need so much choice, bearing in mind the above factors.

Profile of a Viewer

So just who is the cable TV audience? In general, state the ITC, the viewing of cable and satellite channels can be correlated with social class, and reduces as socio-economic position rises. Just what this rather sweeping statement means is unclear, unless you happen to be a socio-economic student! However, what is clear is that a recent sampling found that an impressive 91% of cable subscribers were pleased, or even just quite pleased, with their service. In multi-channel homes, viewers of Sky programmes easily outnumber those watching BBC2 and Channel 4 (whether this would be the case without the two movie channels would be anybody's guess!). More

specifically, among 15 to 24 year olds MTV is enjoyed most; among 25 to 34 year olds, the film channels; while 35 to 54 year olds enjoy the Discovery Channel.

Pacesetters

In the league of cable franchise pacesetters, the Windsor company seems to be setting the installed base pace. Top of the list is Croydon with around 30,000 homes connected, followed by Swindon, Windsor, Aberdeen, and Northampton. However, catching up fast is Cable London who, along with related companies, hold the franchises for the London boroughs of Camden, Haringey, Islington, Hackney and Enfield. Completion of the network in all five London boroughs (which contain some 400,000 homes and 46,000 businesses) will take around seven years, and will represent an investment of £120 million. Telephone network apart, Cable London has the capacity to become an interactive system, making possible such services as home banking and shopping. Meanwhile, according to 'What Satellite' magazine, sales of satellite TV equipment for home use seem to be breaking all records; 116,000 UK systems were sold in December 1991 alone!

Cableships and Cablecosts

The Cable Franchise companies, or Multiple Systems Operators, as Fred Burridge, editor of 'Cabling World' points out, are mostly owned by the major US communications companies such as US West (Cable London), Pacific Telesis, Videotron, and United Artists.

Yet a further cable industry survey (perhaps if there had been fewer surveys and more cable-laying enterprise, matters would have progressed even faster!) reports that 'overwhelmingly, it is the prospect of extra programme choice which turns on the potential subscriber'. The most popular reason for not subscribing was the expense (40% in relation to cable, 44% to dishes), with the next two most popular reasons being that the respondents did not watch television enough to make it worthwhile, and that they were generally satisfied with what the mainstream broadcast channels offered.

Cable London subscribers pay £30 for connection, a £25 deposit and a charge of £10 a month for the basic package of some 20 channels. These include Sky One, Sports and News, MTV, CNN and the local channel 'Grapevine'. However, a year's subscription to this would pay for a good Astra satellite system (with built-in decoder), which would subsequently provide all these channels free of charge (unless Sky foolishly encrypts all of their channels!) – with potential for better picture quality, access to satellite radio and, where broadcast, stereo/multi-lingual sound from all suitably equipped channels thrown into the bargain! Budget multi-satellite systems, capable of re-

ceiving nearly all of the other 'cable' channels, are also available – some retailing for less than £400 (less Video-crypt decoder)! A multi-satellite receiving system also opens up the weird and wonderful world of SNG (satellite news-gathering) feeds as well. The (unbroadcast) spectacle of various politicians, making fools of themselves during General Election outside broadcasts earlier this year, could alone have justified the purchase of such a system!

To get Cable London's movie channels as well as the basic package, the monthly subscription charge varies between £17 and £21 depending on the number of movie channels required. A further £4 per month will obtain foreign language news and entertainment (mostly free to those with satellite systems, particularly those with steerable dishes), as well as the 'adult-orientated' channel, HVC.

Calling on Cable

As licensed telecommunications operators, almost all cable companies are planning to provide telecoms, either as a stand-alone service or in addition to television. According to Fred Burridge, some sources estimate that cable telecoms will account for some 50% of revenues in key cable franchises within the next five years. For both residential and business customers, cable telecoms equate to substantial savings on calls – typically between 10% and 20%. To emphasise the matter, Mercury Communications have announced a dramatic growth of 500% in the number of cable telephony customers connected to their network, while several of the cable franchises are joining forces to provide a local telephone service.

In fact, Cable London, in common with many other operators, thought that the associated telephone service would be of most interest to business subscribers. This is proving not to be the case and almost 85% of TV subscribers are also taking the phone service. The cable runs from the subscriber's premises to the nearest Mercury or international exchange, or into BT. With cable rental being just £5.29 a month per line, the service could soon be a further problem area for BT especially if, as is planned, Cable London install their own exchange within the next two years.

Even so, the operators will have to overcome the inertia of BT subscribers being required to adopt a new telephone number. As Cable London says, many subscribers keep their existing BT line for inward calls until such time as their new cable number is more widely known. Despite reservations, cable, whether providing TV entertainment or a telephony service, looks like being a force to be reckoned with – now, and in the future. Satellite television is also achieving greater popularity than ever before; at this stage, however, it seems that these two somewhat interdependent systems are here to co-exist rather than compete, each fulfilling a particular market requirement.

FEATURES

- ★ Range 30 to 200+ Beats Per Minute
- ★ Quartz Crystal Accuracy
- ★ Easy Setting by Built-in Transducer
- ★ Input for Foot Switch Setting while Playing
- ★ Clear, Easy-to-Read, Digital Display
- ★ Beat Indication by Flashing Display
- ★ Output Available for Extra LED or Sounder or for Hi-Fi Amplifier
- ★ Instant Tempo Check
- ★ Change Speeds Easily

Metrobeat

by Mike Rhodes

As my dictionary has it, "Metronome — Apparatus for sounding an adjustable number of beats per minute and therefore for fixing the tempo of a composition." The mechanical metronome was patented by Maelzel and first manufactured in the early nineteenth century. It is said that the ticking of the metronome inspired the second movement of Beethoven's 8th Symphony, but, be that as it may, things have changed a little since then — but not a lot though!

Most designs of the electronic versions of the metronome now available imitate the original design fairly closely. The latter had a waving pendulum whose speed was varied by adjusting a sliding weight along its length; the range was between 40 and 208 beats per minute and the speed was read from a graduated scale attached to the case. Current versions usually have a calibrated knob which adjusts the speed of some sort of timer, and the output produces an electronically generated click, bleep or the flash of a light emitting diode. This arrangement may be fine for the original purpose of setting the initial speed of a piece of music; where the metronome marking is available. Or for use when you are sitting at the table composing your latest masterpiece and wish to write the marking above your first glorious bar.



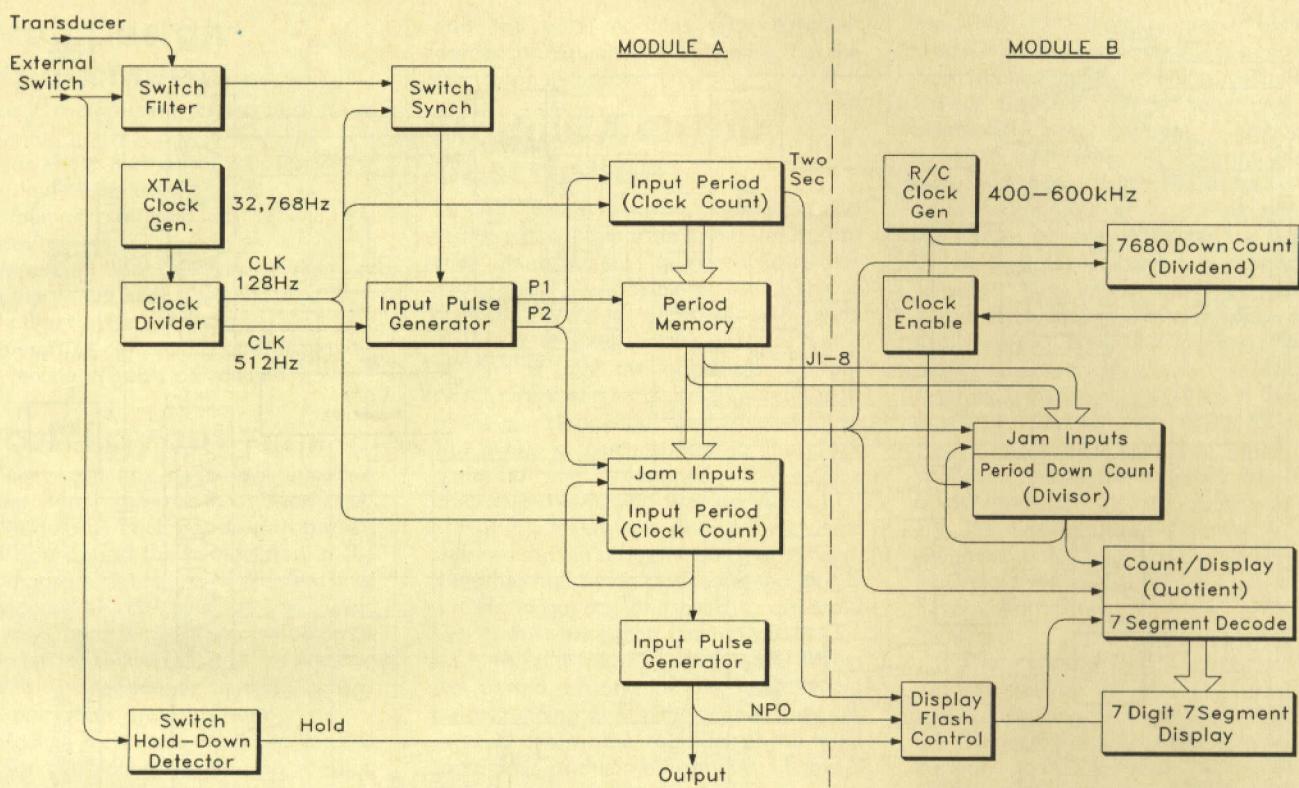


Figure 1. Block schematic diagram of complete Metrobeat.

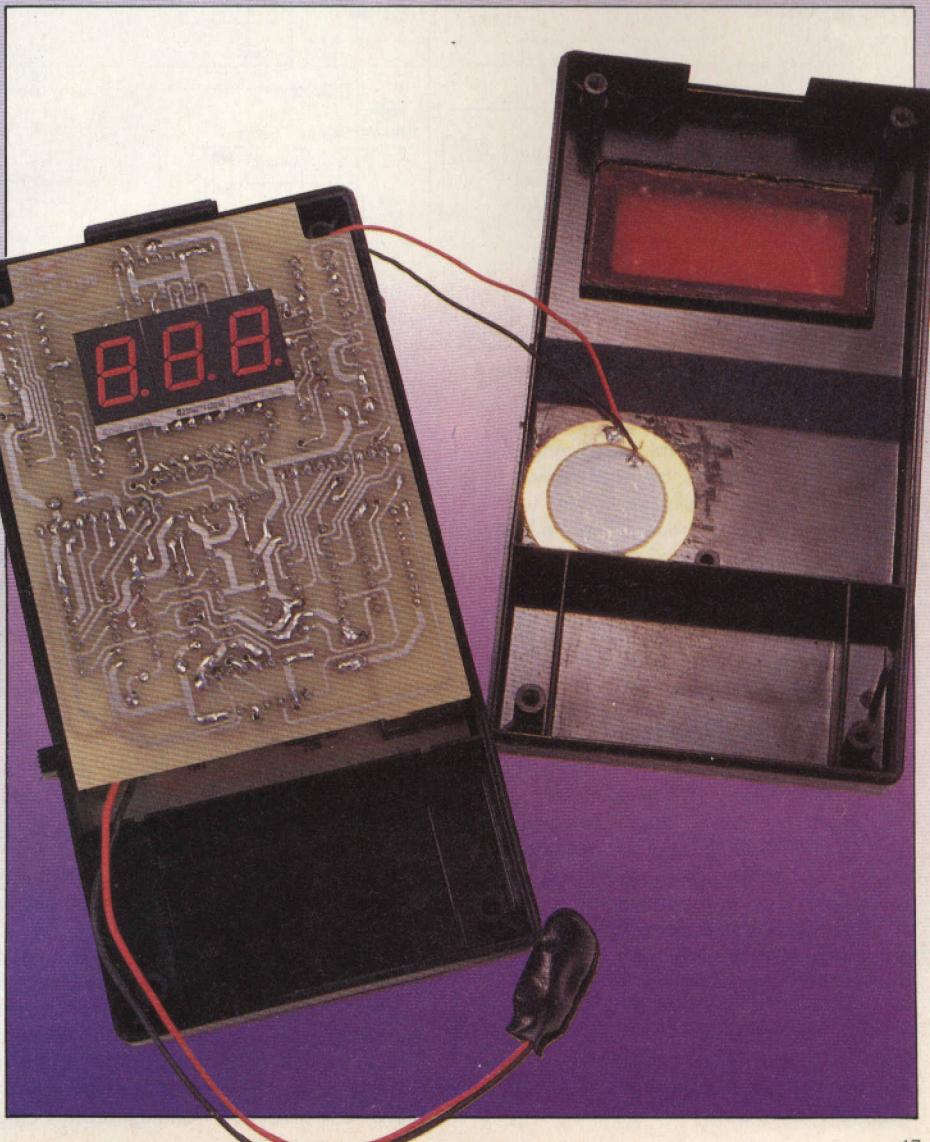
Right: Photo shows the Metrobeat with the lower half of the case removed. The piezo electric transducer can be clearly seen.

But the metronome's facilities can be expanded somewhat more than this with the help of electronics.

For the practicing musician, its usefulness can be extended, for example in the area of performance improvement. Imagine sitting down to your early morning concerto practice when you come across a rhythmic timing problem. You wish to use the metronome to help sort it out.

In the first place, it's necessary to set up the required speed on the selector (and those calibration numbers — almost too small to read). Setting is made easier if there's a metronome marking at the top of the music and you anticipate playing at the suggested speed. It may not be so easy if you're attempting that difficult passage and you wish to try it a little slower. You will then have to select some likely figure and hope that, after you've started playing, you find it's the speed you wanted. If the metronome has been set wrongly, you will have to stop playing, pick it up and reset it, then try again. This could be quite frustrating! Wouldn't it be nice if you could reset and adjust the metronome with a foot switch so that you could carry on playing?

Again, assuming that you have managed to find a suitable speed for the passage concerned, you may then get part way through and find that you are no longer playing in synchronism with the



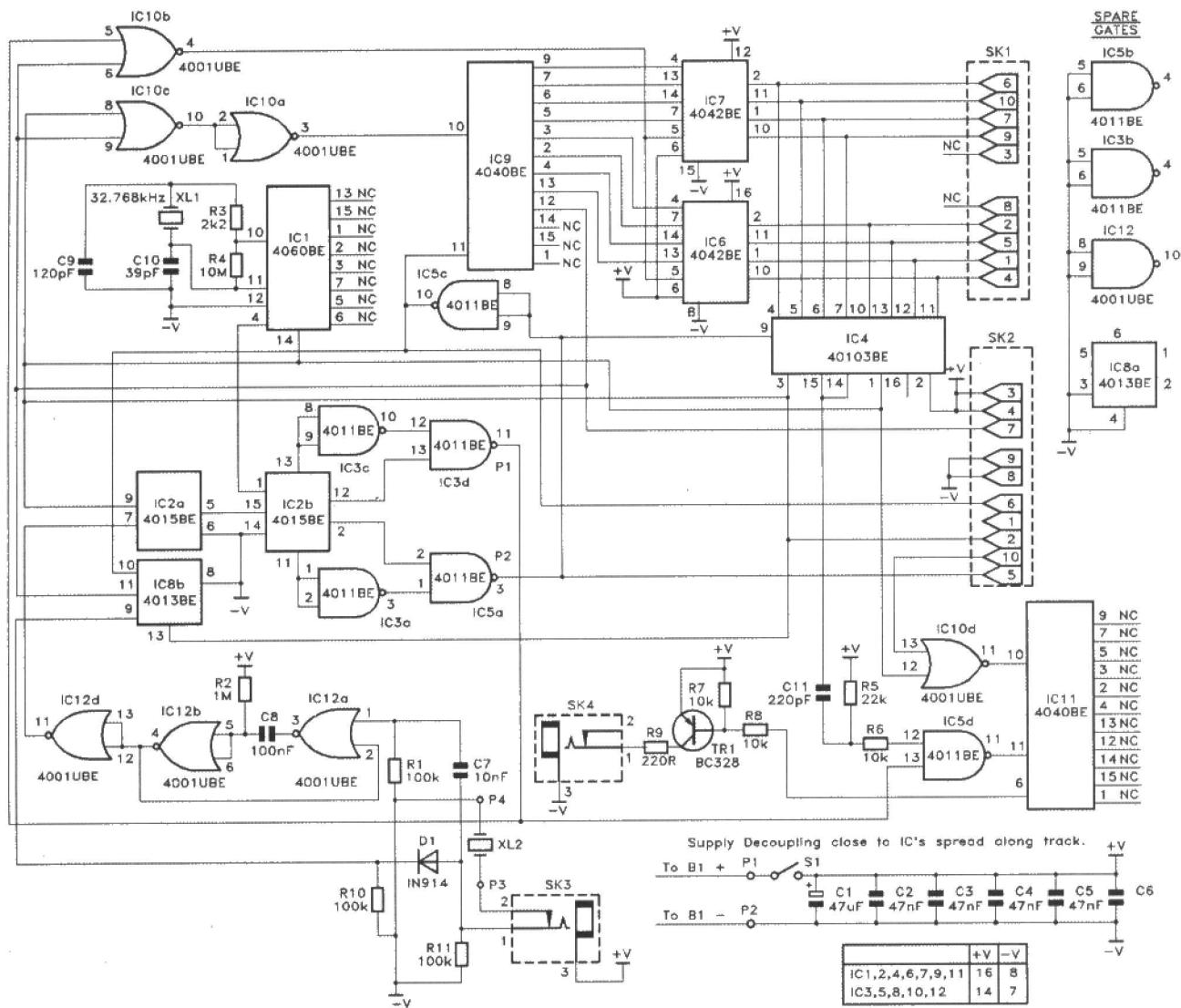


Figure 2a. Circuit diagram of Module A.

metronome. Now this may not be through any fault of your own, in playing the passage, but may be a consequence of there being a musically significant slackening of the pace somewhere in the body of the passage being studied. If this happens, you're pretty well stuck and have to hang about for the next metronome beat to re-synchronise, but if re-synchronising could also be done with a foot switch!

The Metrobeat

With these and other requirements in mind, the idea of 'Metrobeat' was conceived. The device would be operated by a simple switch to input the beat period - by operating the switch on two successive beats of the music, the resulting interval is measured and stored in memory. From this memory a sounding beat or flashing display is derived which repeats at the measured interval. The 'metronome marking' can also be displayed on an easy-to-read, digital display. All this could be contained in a small calculator style box.

The input switch can be used both for re-synchronising and re-setting to the new speed. Re-synchronising is achieved by a single switch action, which causes the beat/flashing display to reset and subsequently repeat at the interval still stored in memory. Re-setting to a new speed is achieved by two successive switch operations, as in the case of the initial setting.

In addition to the above, the device may be 'silenced' by keeping the switch depressed for a period longer than two seconds – the maximum beat period. This ensures that the user can, for instance, stop the flashing light when it is no longer required, without ceasing to play (and before epilepsy sets in!).

Having gone this far, more features suggest themselves. The nature of setting up the Metrobeat means that it has a useful self-training value where a metronome marking has been specified in the music. Having seen the marking, the user can select a beat speed for the music and then have the facility to check whether or not that speed was correct. This is much more effective self-training than being

presented with the normal 'beat on a plate', as it were, as happens with a normal metronome.

Another useful feature is that the Metrobeat lends itself to making a quick measurement of the tempo used, by, for example, different artists on their interpretation of the music.

The Maplin Metrobeat, in its calculator style box, is the basic unit of the system. It has an easy-to-read digital display of the metronome tempo and is set either by tapping the box itself or by use of an external foot switch. The beat frequency output is indicated by the flashing of the digital display, and provision is made so that an external sounder or an extra flashing indicator may be added.

A simple arrangement for adding an audible output is by using a piezo buzzer with built-in driver, such as DC piezo buzzer KU56L. These should be connected with the negative side to the jack plug outer.

It is also possible to route a 'click' signal into an amplifier; useful if a group of musicians are practising together.

Circuit Design Requirements

The basic requirements of the design are as follows:

1. An accurate method of measuring the duration of the input beat.
2. A memory register to record the measured value.
3. A repeating beat generator running at the measured beat rate.
4. An output pulse generator.
5. A means of calculating and displaying the tempo in beats per minute.

Circuit Layout

The Metrobeat has been split into two modules, herein referred to as 'Module A' and 'Module B'. Each has its own printed circuit board, and this is indicated in the block diagram Figure 1 by the dotted line.

Module A contains all the basic measuring, recording and output generating circuits of sections 1 to 4 above and can exist independently, making a very useful unit minus a display.

Module B contains the digital display with its calculating logic and display drivers, and is designed as an 'add-on' unit. It is entirely dependent on Module A

and the two modules plug together sandwich fashion for mounting in the calculator style box.

Module A Circuit Description

Refer to Figure 1, the block diagram and also the circuit diagram in Figure 2a. For time measurement, a crystal oscillator running at 32.768kHz is used. This is divided down in eight stages giving 128Hz and 512Hz in the process.

Inputs from the transducer or foot switch are taken to a pulse generator to produce a clean input for the timing logic. This pulse is synchronised to the clock generator by strobing with the 128Hz clock into a switching synchroniser.

This is taken from one of the four-bit shift registers in a dual 4-bit device, IC2a, the other half being clocked at the higher 512Hz frequency and used to generate two non-overlapping timing pulses, P1 and the following P2, which occur within the period of one of the main timing pulses running at $1/128$ th second. They are used to control the registers of the main 'data flow' and come from pins 11 and 3 of IC5.

Consider two successive inputs (from

the switch, IC1), the time interval between which is to be measured. P2 is generated from the first input and will reset the Input Period Counter IC9 to zero and thus enable it to start counting 128Hz clock pulses. Subsequently P1 from the second input will strobe the count output of the Input Period Counter to a static register, the Period Memory Register, for storage (ICs 6 and 7). This action is carried out between main clock pulses so that the output from the Input Period Counter is stable when the transfer is made. The P2 pulse associated with the second input will reset and start the Input Period Counter again immediately after the transfer. At the P2 pulse time, the data which was strobed to the Period Memory Register is asynchronously 'jammed' (programmed) into the Period Down Counter, IC4 (a programmable 8-stage down counter) so that the period measured will be available for counting down at the end of the P2 pulse.

This Period Down Counter is then decremented by the main 128Hz clock, and on reaching zero will send a pulse to the Output Pulse Generator (group C11 through to SK4) and synchronously reload itself from the Period Memory Register again. Notice that this down

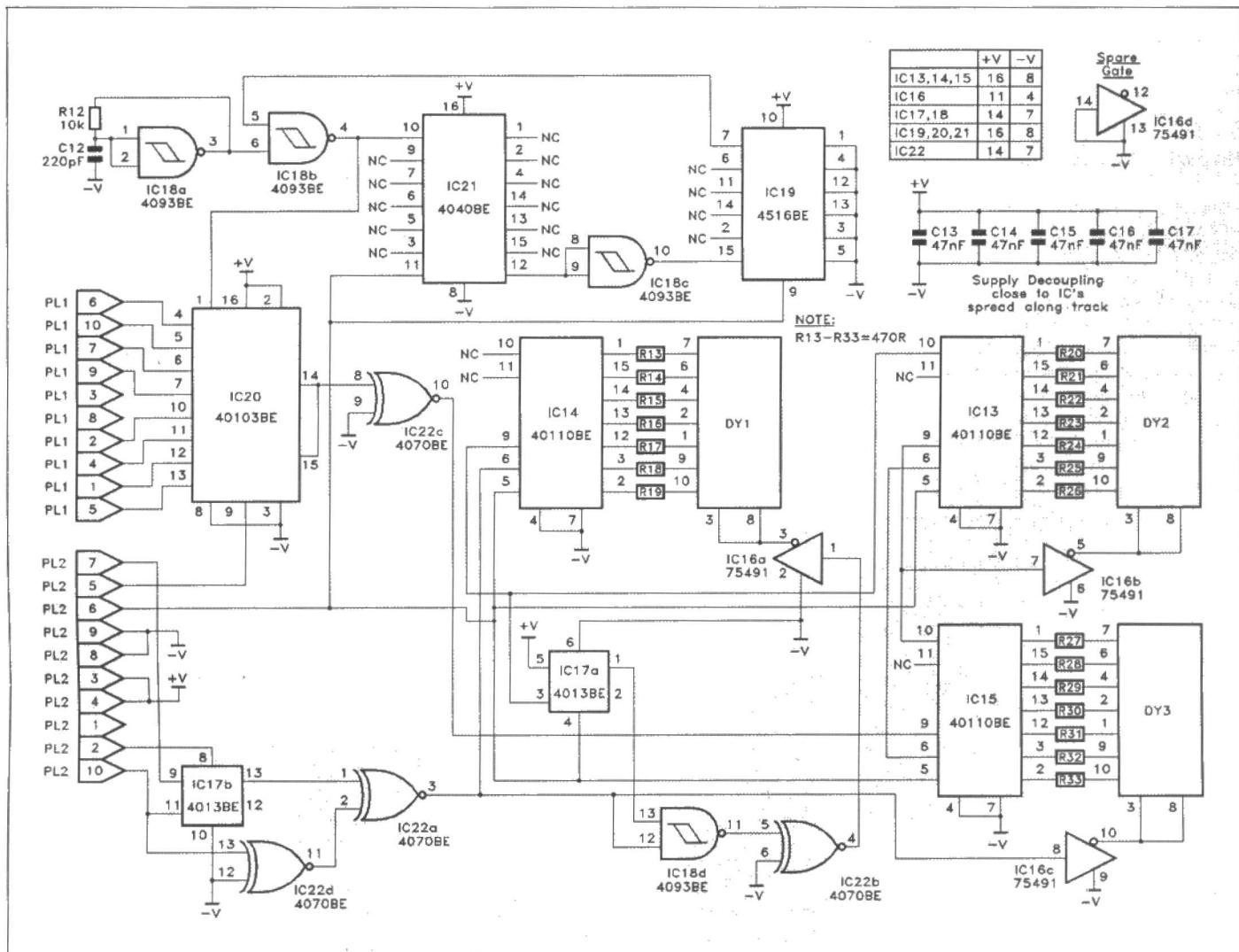
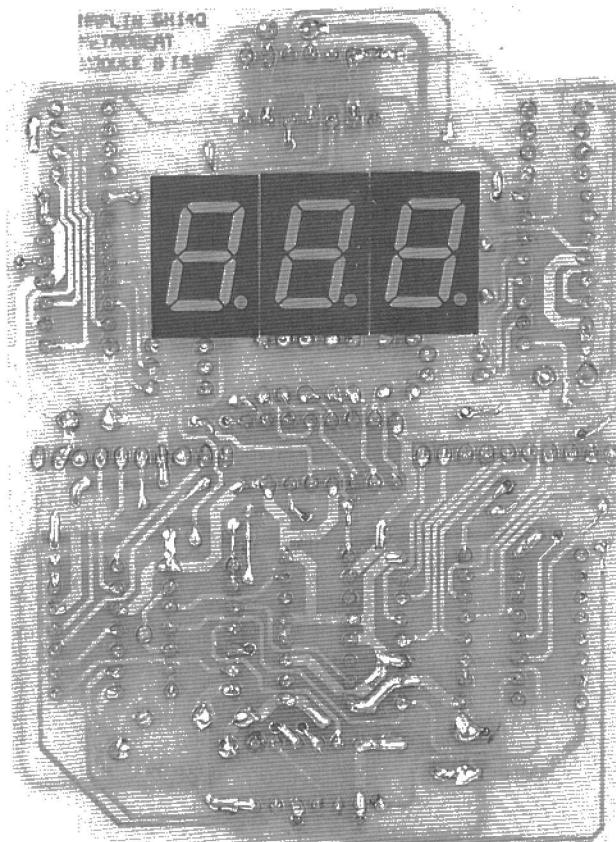


Figure 2b. Circuit diagram of Module B.



Display side of Module B.

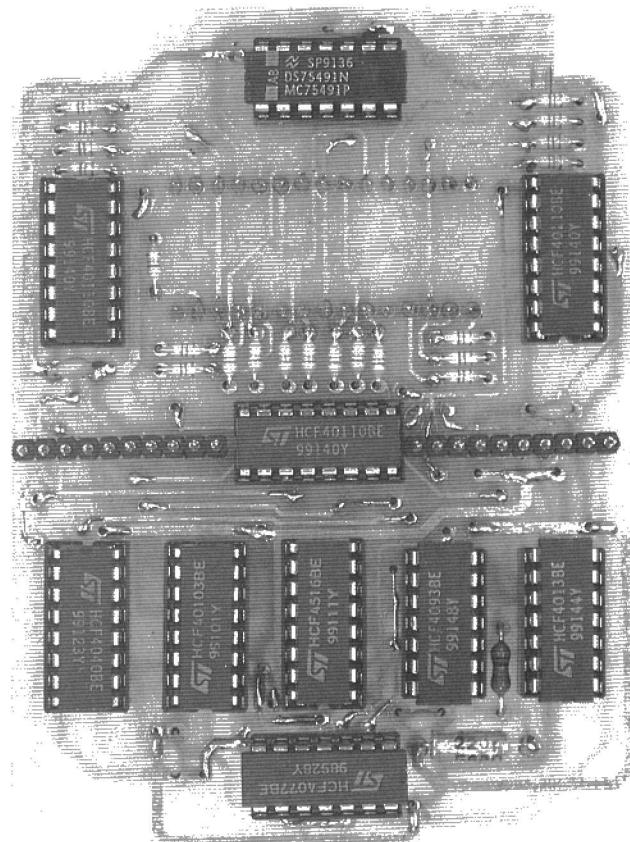
counter circuit counts *one more* than the number loaded when resetting itself asynchronously; the timing of the control pulses P1 and P2, relative to the clock, is arranged such that the number of clock pulses recorded in the Input Period Counter is *one less* than the expected value (see timing diagram Figure 4). The Output Pulse Generator uses a counter (IC11) giving an output duration of 8 clocks to provide a pulse of $1/16$ th second wide for the output display.

It will be clear that, by generating further inputs, the above process will be repeated and the Period Down Counter will be left ticking at the same interval that was last input. The Input Period Counter will automatically stop after 2 seconds, the longest time available, if there are no further inputs.

If the input switch is held down continuously, then, when the Input Period Counter terminates, it will cause the Hold Down Detector (D1, R10 and IC8b) to be set; this is used to blank out the display when no longer required. The is immediately cleared and the display restored if any further inputs are received.

Module B Circuit Description

Again refer to both the block diagram Figure 1 and module B circuit diagram in



Component side of Module B.

Figure 2b. This module contains the three-digit display for showing the period in beats per minute, together with the logic for calculating this number from the measured input period, for decoding the answer and for driving the display.

Calculation Method

The Period Memory Register of Module A stores the interval between two inputs in binary form and in units of $1/128$ th seconds. One minute is represented by $128 \times 60 = 7680$ measured in the same units. To calculate the number of beats per minute for the display, we have to divide one minute, i.e. 7680 units, by the period. Since there is plenty of time to perform this calculation, a simple repetitive decrementing circuit has been used. This repeatedly subtracts the period, one unit at a time, from the dividend, and increments the output display register by one every time the period subtraction has been completed. The output is then decoded to seven segment format for the display.

Circuit Details

The Module B Period Down Counter (IC20) is loaded directly from the Period Memory Register of Module A by the P2 pulse and at the same time, the dividend (7680) down counter is loaded (IC21). A separate R/C clock, running at about 500kHz (R12, C12 and IC8a and b), is

used to decrement the divisor and dividend simultaneously.

Each time the divisor reaches zero, it resets itself to the value stored in the Period Memory Register and increments the Quotient Counter Register. When the dividend becomes zero, the process stops and the number in the Quotient Counter Register is the number to be displayed.

The Quotient Counter Register consists of three integrated circuits (ICs 15, 13 and 14), each of which contains a decimal counter with seven segment decode and display drive circuitry. Outputs are active high and connected to appropriate elements of the LED displays via 470Ω resistors, which set the output current to a suitable value. The common cathodes of the displays are driven by a dedicated quad driver IC (IC16), which is normally only switched on when the output pulse Generator of Module A is active. This drive is modified in the case of the most significant digit to provide leading zero blanking. The drive to all three digits is also controlled from the Input Period Counter of Module A such that the output is displayed for the 2 second period following the last input, the beats being marked by blanking the display at beat frequency. At the next beat, after 2 seconds has expired, the display switches to normal off and flashes to mark the beats.

Module A Construction

As previously explained, Module A can be used to make a complete Metrobeat without the display module (Module B) and should be assembled and fully tested first.

The Module A PCB legend is shown in Figure 3a.

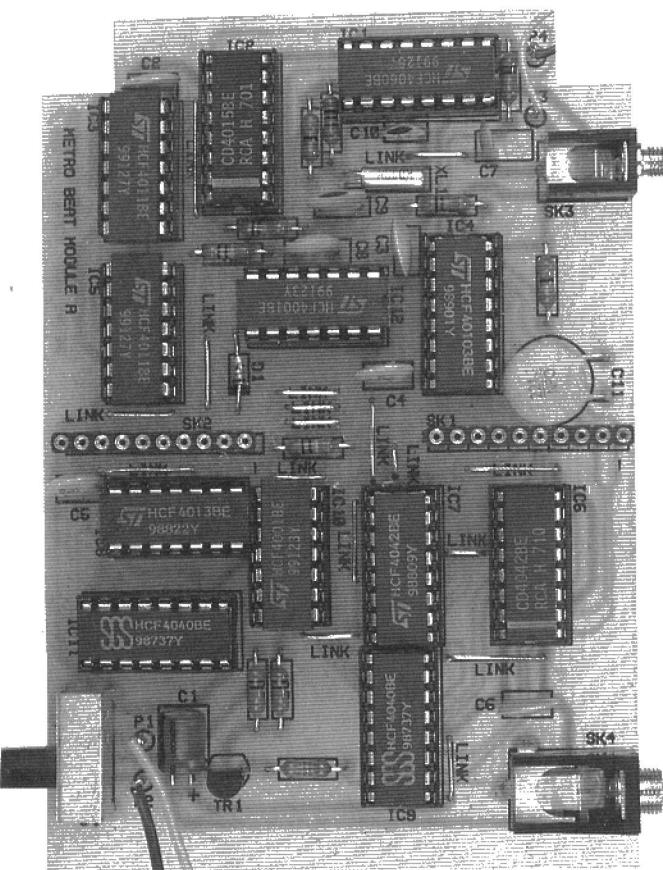
When assembling the components on the PCB, the CMOS integrated circuits should be left until last to reduce handling to a minimum. The following assembly order makes things easier; pay particular attention to careful soldering since, as you probably know, this is the major source of

subsequent faults. Fit the following:

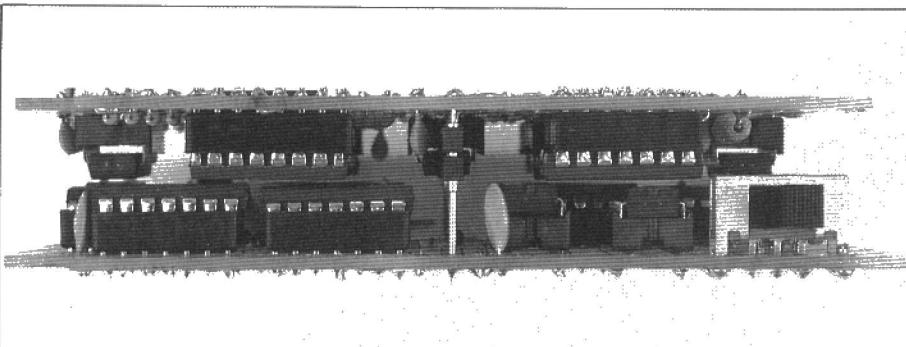
1. Wire links (17 links total).
2. All resistors.
3. All capacitors, crystal XL1 and transistor TR1.
4. Jack sockets, inter-module connectors and slide switch.
5. Battery clips and transducer XL2.

At this stage it is a good idea to ensure everything is earthed before:

6. IC sockets. Ensure that the notch Pin 1 marker on the IC package aligns with marker on the PCB legend.
7. Insert the ICs keeping handling to a minimum.



Component side view of Module A.



Side view showing how the modules plug together.

Module A Inspection and Testing

A close inspection of the soldering with a powerful magnifier is highly recommended. If the module has been correctly assembled and carefully soldered, you can expect it to work first time. To simplify the testing of Module A, it is convenient to have an external switch connected and also an output detector. Connect a 'push-to-make' switch, preferably the remote foot switch (Order Code KW02C), to the 2.5mm jack input. Connect an LED (or piezo buzzer) to the 3.5mm jack output (negative on the outer). Connect the 6V battery or a bench power supply and switch on. Test as follows:

Testing Sequence

1. Press the switch once, then again after about 1 second; the LED should flash each time the switch is pressed and, afterwards, continue to flash at the same rate, i.e. about once per second.
2. Depress the switch and hold down for a period longer than 2 seconds; the LED should stop flashing.
3. Press the switch just once; the LED should recommence flashing at the same rate as before (approximately once per second).
4. Try different flash rates up to the maximum of 2 seconds period.

If all is well, try the action of the transducer input by tapping it with (say) a pencil. The different flashing rates should be achieved as with the switch, but the 'hold down' action cannot be used with the transducer.

If all is still well, proceed with Module B or else diagnose the fault – see Module A diagnostics.

Module B Construction

Having completed the testing of Module A, proceed with the assembly of Module B.

The Module B PCB legend is shown in Figure 3b.

Assemble the PCB components in a similar order to those for Module A:

1. Resistors and capacitors.
2. Connectors for plugging into Module A.
3. IC sockets.
4. Displays. Note that these are mounted on the *opposite* side of the board to the ICs and the other components.
5. Insert the ICs, keeping handling to a minimum.

Module B Inspection and Testing

Inspection and testing should be followed as for Module A, but now the output will be presented on the seven segment display, which should indicate the metronome 'marking', i.e. the number of beats per second. This can be checked approximately with a watch – one second intervals should read 60, the slowest beat of one every 2 seconds should read 30, etc.

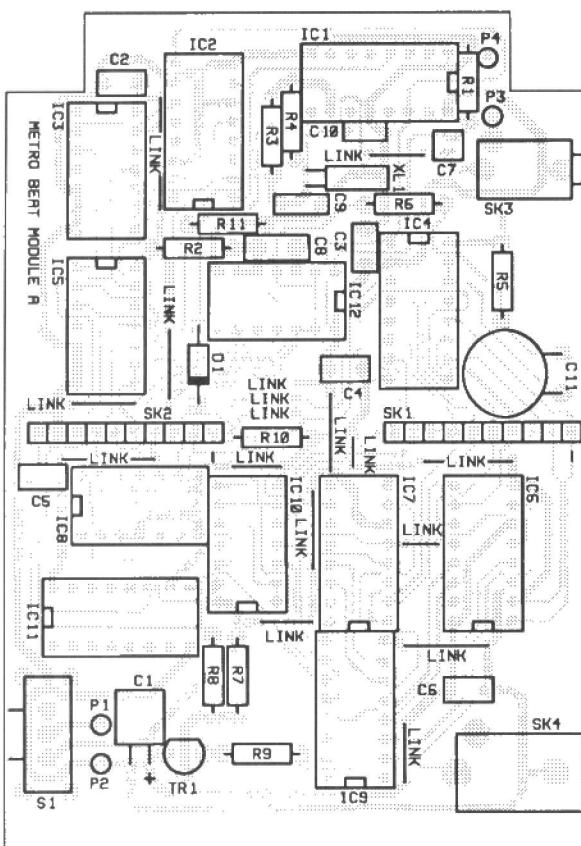


Figure 3a. PCB legend of Module A.

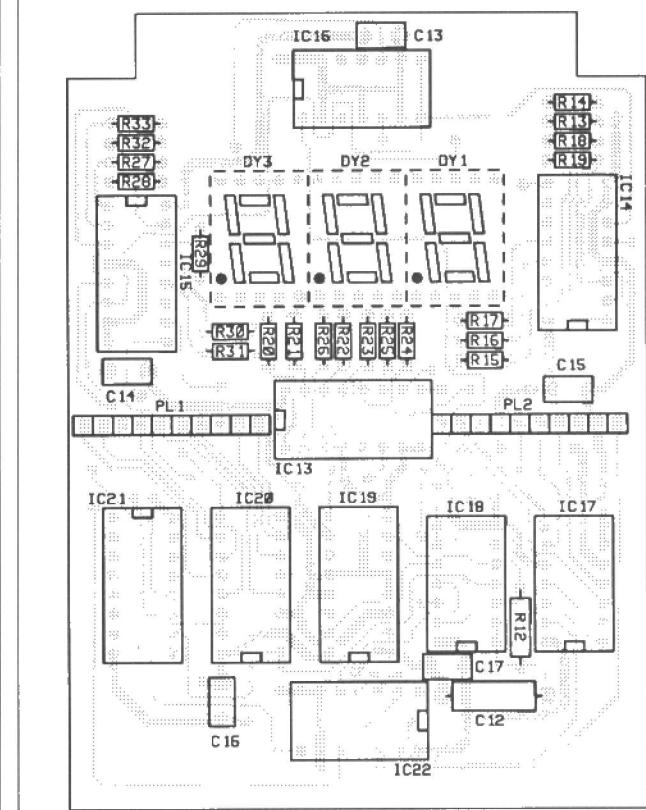


Figure 3b. PCB legend of Module B.

MODULE A TIMING WAVEFORMS

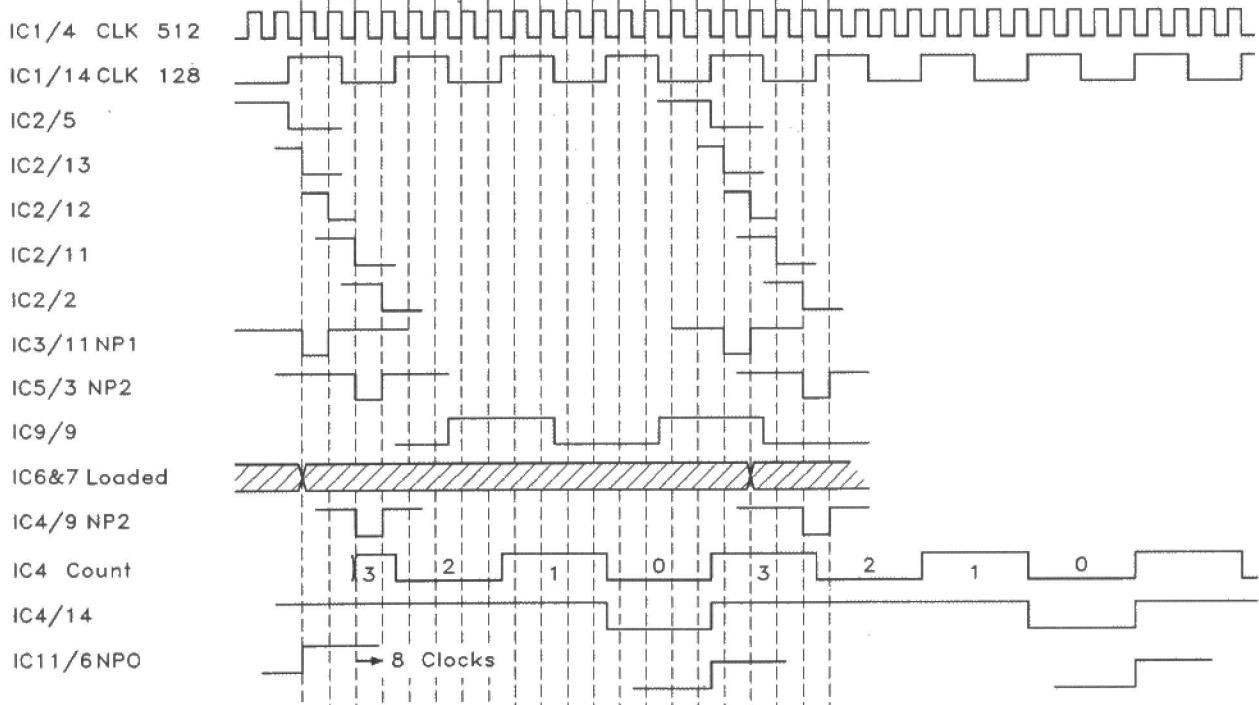


Figure 4. Timing diagram, illustrating the waveforms at the listed IC pins.

Box Lower Half Drilling and Cut Out

All dimensions in mm

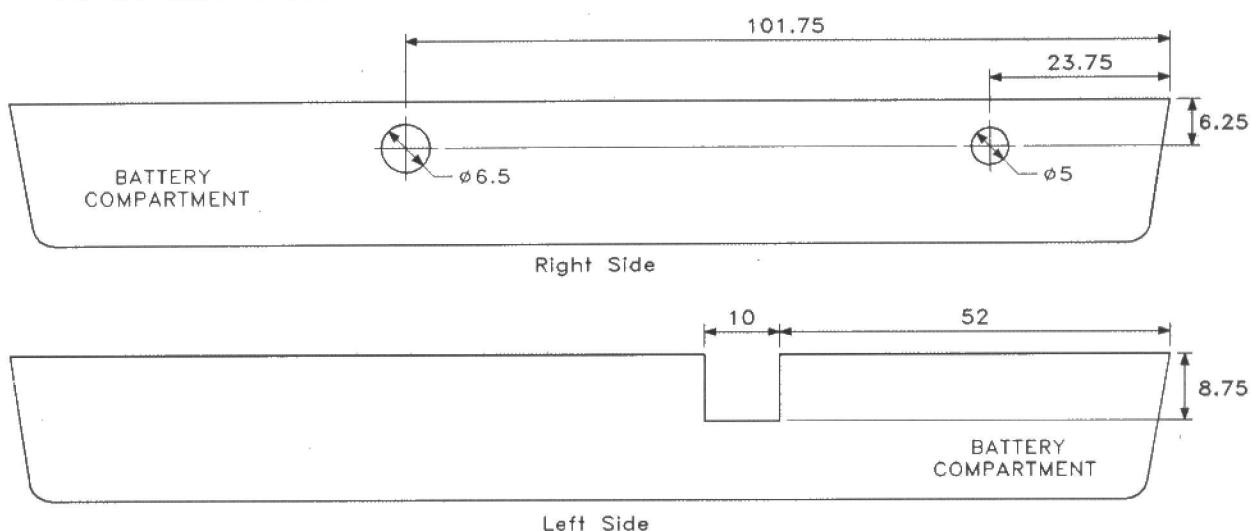
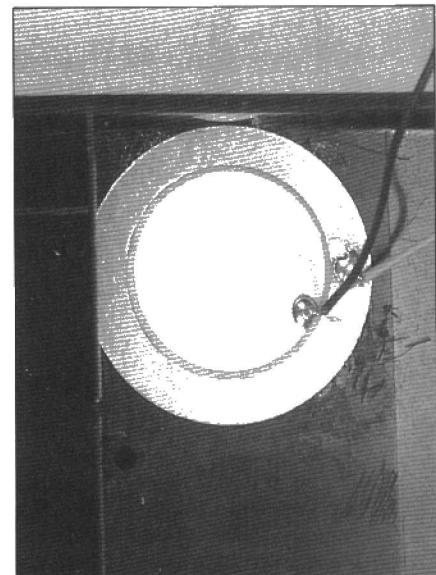
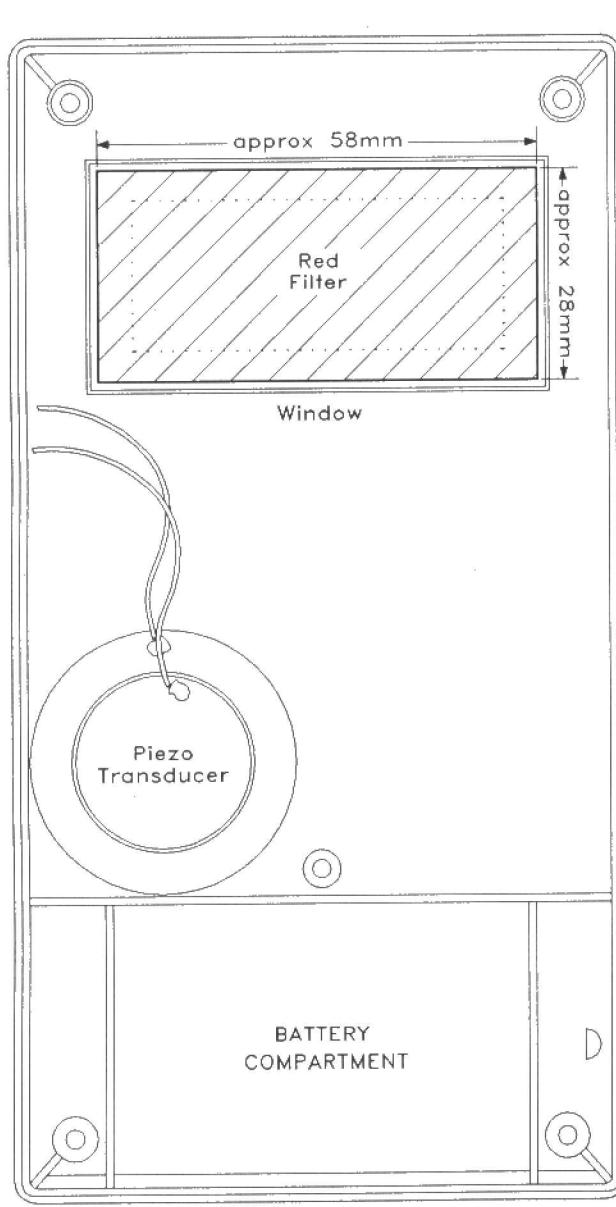


Figure 5. Box drilling details.



Close up of the piezo transducer.

The most significant digit of the display should be blanked for counts less than 100; the beat itself will be indicated by brief blanking of the whole display during the first 2 seconds from the last press of the switch, and thereafter the display will be normally switched off and flash only on the beat.

If these functions are all working correctly, it is time to sort out the case, otherwise diagnose any fault — see Module B diagnostics.

Module A Diagnostics

Suggested things to check:

1. Check +V and -V on each IC.
2. Check crystal oscillator running and output IC1 pin 4 (512Hz) and IC1 pin 14 (128Hz).
3. Check transducer LX1. Input to IC12 pin 1 should give an oscillation lasting around 5 milliseconds after being tapped.

Figure 6. Fitting the red display filter and transducer XL2.

PC Sound Generator

Applications

- ★ Sound Effects
- ★ Computer Music

Features

- ★ Plugs into PC Expansion Slot
- ★ Alterable Base Address
- ★ Six Frequency Generators
- ★ Two Noise Generators
- ★ Two Six Channel Mixers
- ★ Envelope Shapers and Amplitude Control
- ★ Simple Construction



by Mel Saunders

"Please Don't Play it Again, (PC) Sam!"

If IBM PCs (or their clones) lack anything, it must be decent sound. Displays can be upgraded in resolution and to colour, memory can be expanded or extended, and floppy/hard disk drives of all shapes and sizes can be added – to say nothing of plotters, scanners, etc...! As for software, there is more than enough to cover just about each and every application that you may care to consider. Even then, you can write your own programs using one of many available languages like easy BASIC, faster and structured Turbo PASCAL, 'C' or assembler/machine code.

Enter the SAA1099!

Despite the advancements made in these other areas, the PC sound provision remains primitive – a squeaky little speaker with only one voice! This project details a stereo sound PC card based around the Philips SAA1099 stereo sound IC. Each stereo channel possesses 3 tone generators and a noise generator, and each tone generator can be programmed over 8 octaves (each of which consists of 256 tones). The amplitude of each tone generator is programmable to 16 levels. In addition there are two (one for each channel) envelope generators; these can modulate the tone with sawtooth and triangular waveforms, in single or continuous mode, providing various effects like attack and decay. Such effects (see Table 4) include attack, delay, sirens, alarms and bomb drops – not to mention music. The complete tone range, 31Hz to 7.81kHz, is shown in the table below:

Octave	Frequency Range
0	31 to 60Hz
1	60 to 122Hz
2	122 to 244Hz
3	245 to 488Hz
4	489 to 976Hz
5	978 to 1.95kHz
6	1.95 to 3.9kHz
7	3.91 to 7.81kHz

As can be seen, the highest (fundamental) frequency generated by unit is 7.81kHz; well in excess of the 4.2kHz fundamental that the piccolo, the highest pitched musical instrument, can produce. This range, along with the presence of noise generators, ensures that there is enough versatility for sound effects of all kinds.

Circuit Description

1. The SAA1099 Sound Generator IC

Looking at the block diagram of Figure 1, it can be seen that the SAA1099 chip is one of many where the data and address information share the same input pins, a type of multiplexing generally known as the MOTEI (MOTOROLA- INTEL) system.

In this case, the data on these pins is the address of one of the 32 internal registers when the address line (A0) is high. Conversely when A0 is low, the data on the same pins is the data to be written to one of these internal registers (see Table 1). The rest of the control logic is fairly straightforward. Figure 1 shows us other very interesting things too! Note that a left channel sound component is also fed to the mixer/output stage of the right channel, and vice versa. Each frequency generator has its own mixer for adding noise; frequency generators 0 and 3 can also be used to provide the basic frequencies for the noise generators – note, however, that they cannot generate sound and noise simultaneously. In a similar fashion, frequency generators 1 and 4 can provide signals for the two envelope controllers – but, again, not when they are acting as sound generators. The resistor connected to pin 6 provides the reference current used to bias the outputs, which are current sinks and need a pull-up resistor to +5V.

2. Getting Registered

Tables 3 and 4 show a better breakdown of the internal bit functions of the registers; note that some are split into two (upper and

Select	Data Bus Inputs									Operations
	A0	D7	D6	D5	D4	D3	D2	D1	D0	
0	D7	D6	D5	D4	D3	D2	D1	D0		Data for internal registers
1	X	X	X	A4	A3	A2	A1	A0		Internal register address

Where X = don't care state.

Table 1. External memory map of the SAA1099.

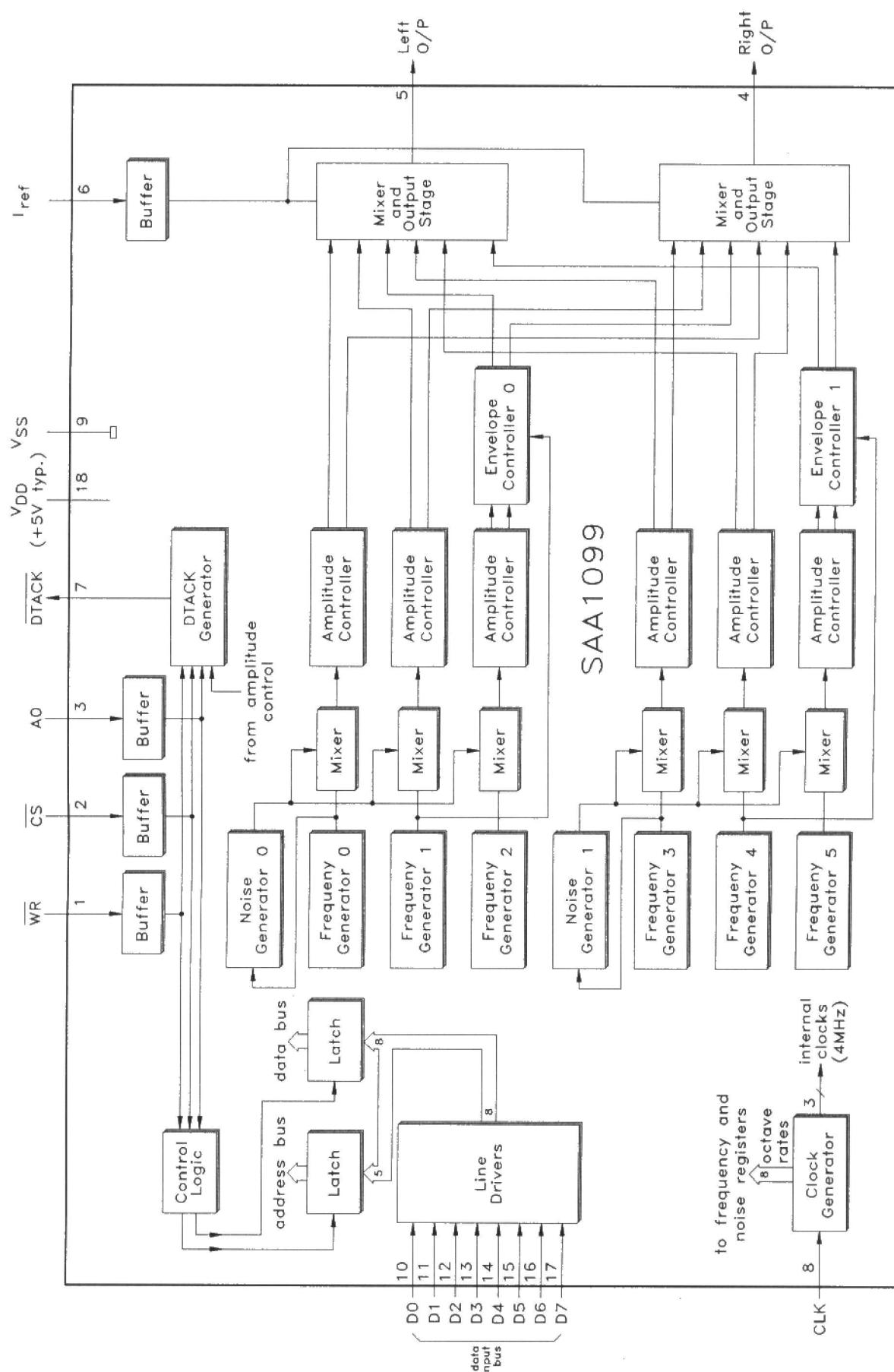


Figure 1. Internal schematic block diagram of the SAA1099.

lower) groups of 4 bits. Registers 0 (00H) to 5 (05H) are the amplitude controllers for the six frequency generators; the 4 LSB (Least Significant Bits) control the left hand output, while the 4 MSB (Most Significant Bits) control the right hand output. Registers 8 (08H) to 13 (0DH) control the actual tone produced by the frequency generators; these work along with registers 16 (10H) to 18 (12H), the octave registers, to produce the final tone.

The noise generators provide 'coloured' noise, which is 'random' noise centred around specific frequencies. In the case of the SAA1099, these centre frequencies are 31.5kHz, 15.6kHz, 7.6kHz – or a band of frequencies ranging from 61Hz to 15.6kHz if the noise source is driven by the appropriate frequency generator (0 or 3). The two lower bits in each nibble of register 22 (16H) take care of this, register 21 (15H) enables the noise onto the output via the mixer. Coloured noise is very useful for producing explosion and steam train sound effects, for example.

The envelope control registers 24 to 25 (18 to 19H) can provide the following functions; no envelope, single and continuous attack or decay, single or continuous attack/decay, triangle or sawtooth waveforms (see Figure 2). In addition, the right channel can be programmed with the inverse waveform of the left channel. Table 5 describes the functions of the seven bits that control the envelopes. Note that En7 (D7) is the 'enable' bit, and can switch the envelope on or off. If no sound channels are switched on, the envelope itself will appear at the output, the circuit thus becoming a multi-function waveform generator with a top frequency of about 1kHz. Another interesting fact is that the start of an envelope can be triggered by the WR pulse; as a result, envelope speed can also be controlled by continually writing to the SAA1099 address latch.

Another important register is 20 (14H). At this address, each of the six lower bits acts as an 'enable' for a particular frequency generator (see Table 2), making it possible to preset a range of tones and switch them on and off as required! Similarly, register 21 (15H) controls the noise/frequency/mixers for the 6 frequency generators. The final register is 28 (1CH). Here, data bit D0 is the 'sound enable' bit, being able to switch all sound channels on or off (D0=1 for on). When set high, bit D1 of this register resets and synchronises all sound generators.

Once you have written a register address to the SAA1099, you can then keep writing to and updating that register – there is no need to keep repeating the address; the SAA1099 stores it in the address latch until you change it.

Some of the registers may seem a little strange, in particular the split ones. How do you use them? It is, in fact, very simple! Take the first register (0), for example. This is the amplitude control for frequency generator 0, the first four bits (reading right to left) controlling the volume of the left output (the remaining 4 bits, as you can see from Table 2, control the right channel.) 4 bits give you 16 different values, 0 to 15

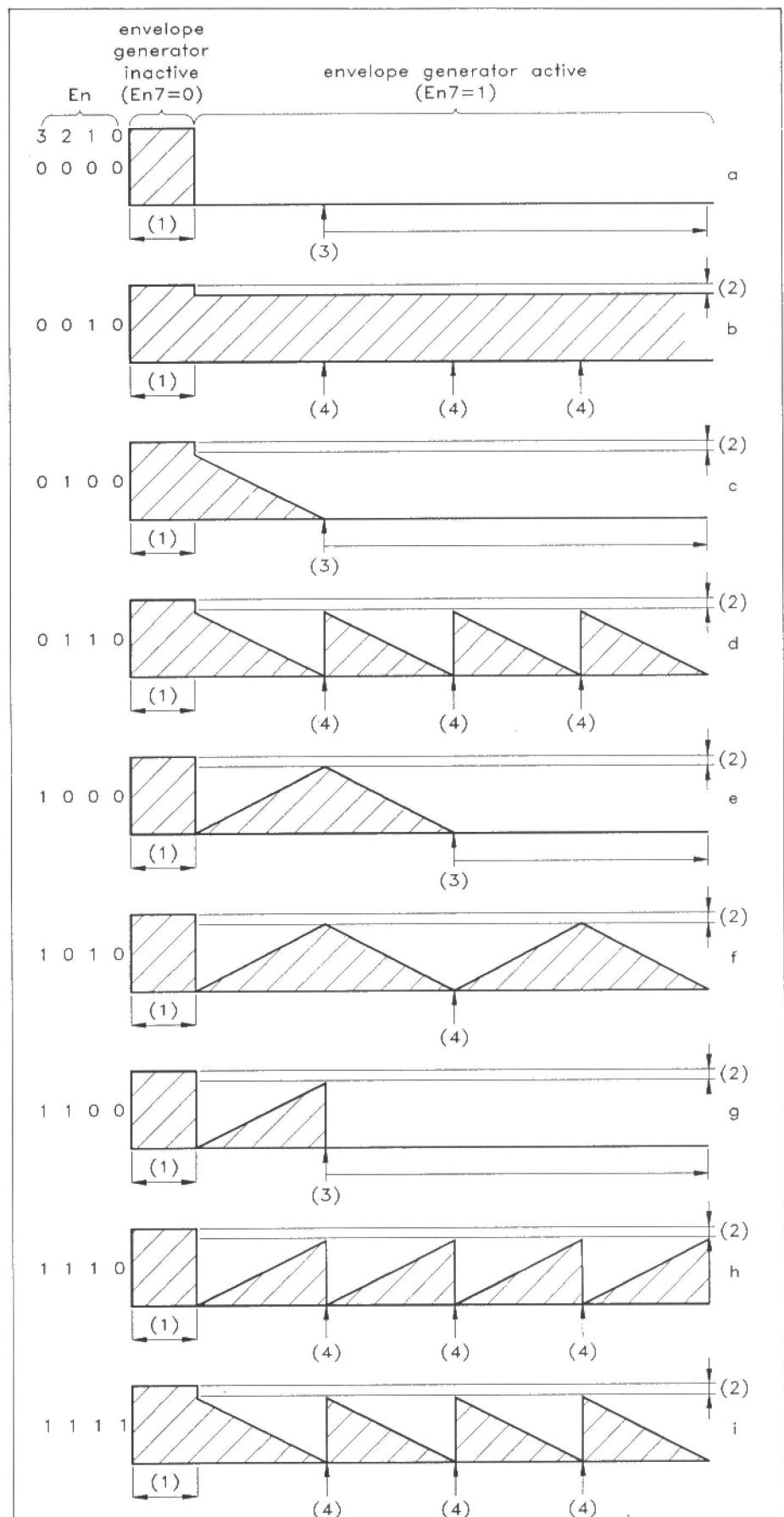
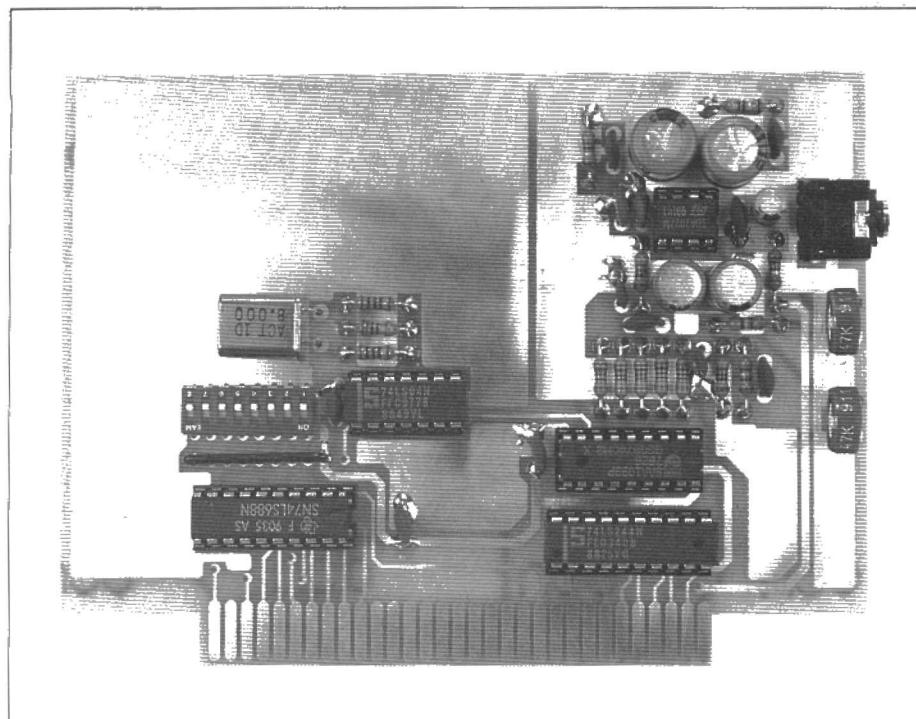


Figure 2. Envelope waveforms produced by the SAA1099. In brackets: (1), the level at this time is under amplitude control only (En7 = 0, no envelope). (2), when the generator is active (En7 = 1) the maximum level possible is $15/16$ ths of the amplitude level, rounded down to the nearest 8. When the generator is inactive (En7 = 0) the level will be $1/16$ ths of the amplitude level. (3), after position (3) the buffered controls will be acted upon when loaded. (4), at positions (4), the buffered controls will be acted upon if already loaded. Waveforms 'a' to 'h' show the left channel (En0 = 0); left and right components have the same envelope. Waveform 'i' shows the right channel (En0 = 1; right component inverse of envelope applied to left).



The assembled PC Sound Card.

Register Dec	Register Hex	D7	D6	D5	D4	D3	D2	D1	D0	Function
0	00H	AR3	AR2	AR1	AR0	AL3	AL2	AL1	AL0	Amplitude Freq 0
1	01H	AR3	AR2	AR1	AR0	AL3	AL2	AL1	AL0	Amplitude Freq 1
2	02H	AR3	AR2	AR1	AR0	AL3	AL2	AL1	AL0	Amplitude Freq 2
3	03H	AR3	AR2	AR1	AR0	AL3	AL2	AL1	AL0	Amplitude Freq 3
4	04H	AR3	AR2	AR1	AR0	AL3	AL2	AL1	AL0	Amplitude Freq 4
5	05H	AR3	AR2	AR1	AR0	AL3	AL2	AL1	AL0	Amplitude Freq 5
8	08H	F07	F06	F05	F04	F03	F02	F01	F00	Frequency Tone 0
9	09H	F17	F16	F15	F14	F13	F12	F11	F10	Frequency Tone 1
10	0AH	F27	F26	F25	F24	F23	F22	F21	F20	Frequency Tone 2
11	0BH	F37	F36	F35	F34	F33	F32	F31	F30	Frequency Tone 3
12	0CH	F47	F46	F45	F44	F43	F42	F41	F40	Frequency Tone 4
13	0DH	F57	F56	F55	F54	F53	F52	F51	F50	Frequency Tone 5
16	10H	X	OC12	OC11	OC10	X	OC02	OC01	OC00	Octave 1: Octave 0
17	11H	X	OC32	OC31	OC30	X	OC22	OC21	OC20	Octave 3: Octave 2
18	12H	X	OC52	OC51	OC50	X	OC42	OC41	OC40	Octave 5: Octave 4
20	14H	X	X	FE5	FE4	FE3	FE2	FE1	FE0	Frequency Enable
21	15H	X	X	NE5	NE4	NE3	NE2	NE1	NE0	Noise Enable
22	16H	X	X	N11	N10	X	X	N01	N00	Noise 1/Noise 0
24	18H	E07	X	E05	E04	E03	E02	E01	E00	Envelope Gen-0
25	19H	E17	X	E15	E14	E13	E12	E11	E10	Envelope Gen-1
28	1CH	X	X	X	X	X	X	RST	SE	Reset Sound EN

All 'X's above should be written as zeros.

An 'L' in a column indicates left channel control.

An 'R' in a column indicates right channel control.

Note: registers are not numbered consecutively.

Data Bus Inputs								8 Register bits	
Group 2				Group 1					
D7	D6	D5	D4	D3	D2	D1	D0		
128	64	32	16	8	4	2	1	Decimal values	

Table 2. Register overview.

(any combination of 0, 1, 2, 4, 8), which correspond to 16 levels of volume. The 4-bit group controlling the right volume works in just the same way as those for the left, but the actual value you now enter will be any combination of 0, 16, 32, 64 and 128. Again, there are 16 values and the effect is still the same.

The table below shows the 8 bits in the register. Some functions use the whole 8 bits, while others only use 3 or 4 bits. To set, say, frequency generator 0 (right channel) to maximum volume you write a number to the register with bits D7 to D4 set high (i.e. 240), the four remaining bits D3 to D0 determining how the left hand volume is set. You can, if you wish, effect volume changes on both channels by writing to just one register. This is very useful when you want to 'pan' a sound from left speaker to right speaker!

3. Addressing your PC

When installing the card in your PC, the area of the system map in which it resides is defined by the settings of SW1, a DIL package of 8 SPST switches. When a particular switch is 'ON', the complementary ('Q') input of that address line is set low (0). For a base address of 300H then, we set;

With reference to the circuit diagram in Figure 3, IC1 (74LS688) is an 8-bit comparator, comparing the 8 address bits presented by the PC on pins 22 to 29 of PL1A (A2 to A9) with the 8 bits on its inputs Q0 to Q7 set by the DIL switch. Q0 to Q7 correspond to the user-definable address at which the computer will recognise the card. If equal the P=Q output at pin 19 is set low (0), thus acting as an active low Chip Select/Enable signal for IC3 and IC4, otherwise it is set high (1) and the devices are disabled.

IC3 is a 74LS24 tristate octal buffer, which buffers the PC's data bus (pins 2 to 9 of PL1A) so that there is no risk of the card loading it too much. IC3 has two active-low enable inputs, G1 and G2 (pins 1 and 19); these, and the active low CS (Chip Select) input of IC4 (the SAA1099), are activated by the P=Q output of IC1. When not selected, IC3 effectively isolates the card from the PC's data bus. The enable output from IC1 is also ORed in IC2 with the host PC's IOW (Input/Output Write) signal. As a result, when both are low (0) IC4 is supplied with an active and valid WR (Write) signal, and the data from the data bus is written to the chip. There is one other system signal that must be considered in the decoding; this is AEN (Address ENable), and it is routed from the PC via pin 11 of PL1A. This line is always low for normal CPU operation and is used as an overall enable signal.

4. Sound Generation – The Audio Side

The SAA1099 IC requires an 8MHz external clock input, which is provided by a 8MHz crystal in a standard TTL circuit using two of the NOR gates of IC2

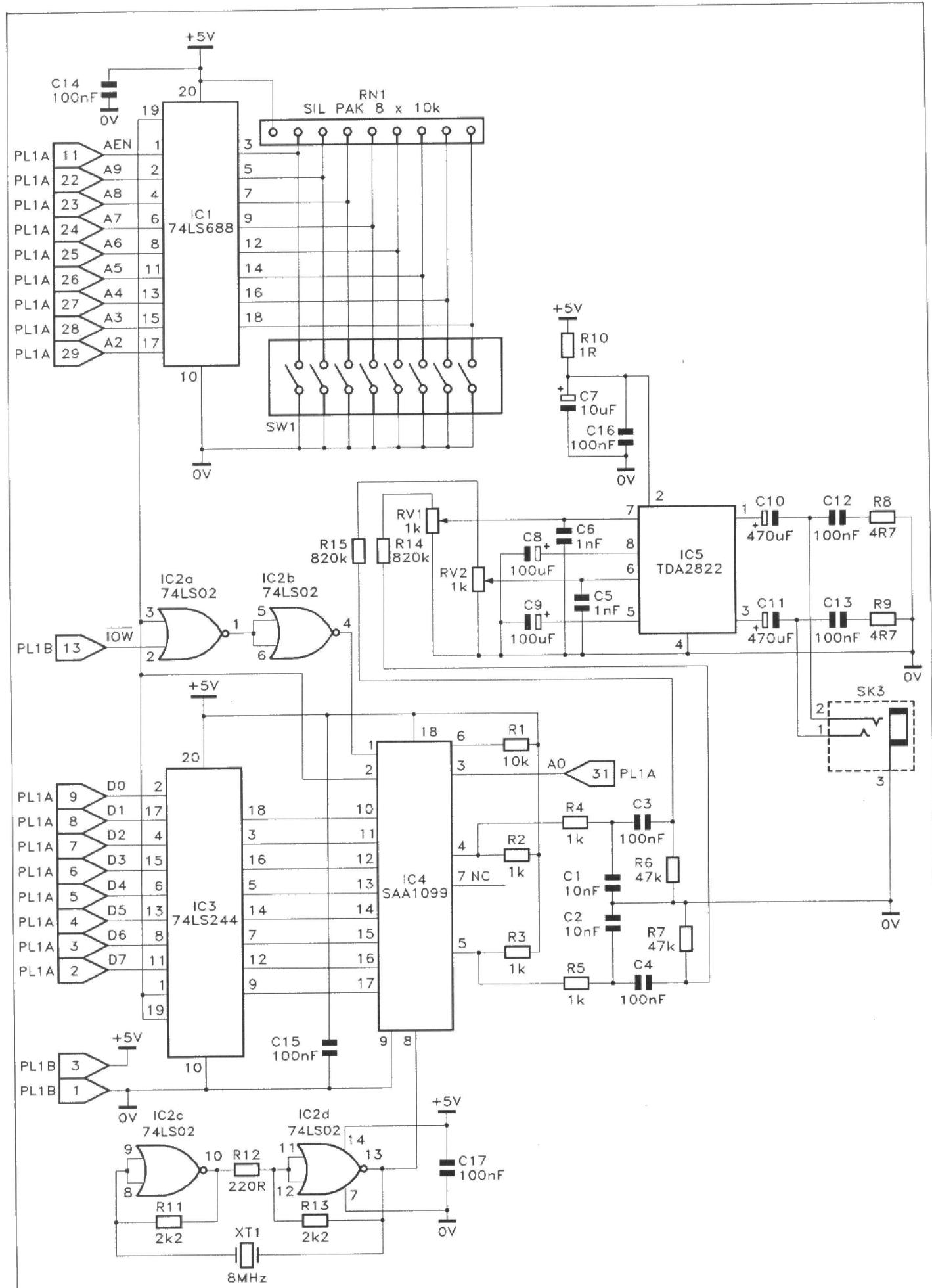
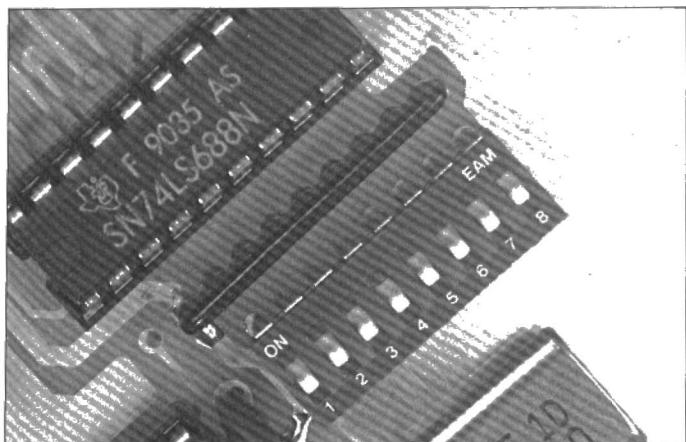
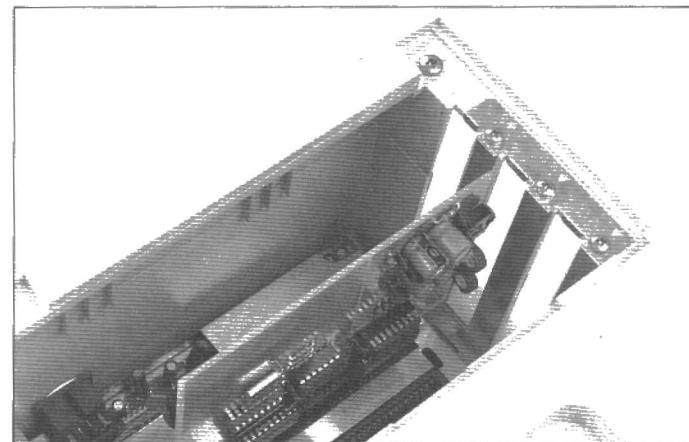


Figure 3. The circuit diagram of the PC Sound Card.



Close-up of the address selection switches.



The PC Sound Card inserted in a PC.

Bit	Description
ARn3; ARn2; ARn1; ARn0 (n = 0.5)	4 bits for amplitude control of right channel 0 0 0 0 minimum amplitude (off) 1 1 1 1 maximum amplitude
ALn3; ALn2; ALn1; ALn0 (n = 0.5)	4 bits for amplitude control of left channel 0 0 0 0 minimum amplitude (off) 1 1 1 1 maximum amplitude
Fn7 to Fn0 (n = 0.5)	8 bits for frequency control of the six frequency generators 0 0 0 0 0 0 0 0 lowest frequency 1 1 1 1 1 1 1 1 highest frequency
On2; On1; On0 (n = 0.5)	3 bits for octave control 0 0 0 lowest octave (31Hz to 61Hz) 0 0 1 (61Hz to 122Hz) 0 1 0 (122Hz to 244Hz) 0 1 1 (245Hz to 488Hz) 1 0 0 (489Hz to 977Hz) 1 0 1 (978Hz to 1.95kHz) 1 1 0 (1.96kHz to 3.91kHz) 1 1 1 highest octave (3.91kHz to 8.81kHz)
FEn (n = 0.5)	frequency enable bit (one tone per generator) FEn = 0 indicates that frequency 'n' is off
NEn n = 0.5	noise enable bit (one tone per generator) NEn = 0 indicates that noise 'n' is off
Nn1; Nn0 (n = 0.1)	2 bits for noise generator control. These bits select the noise generator rate (noise 'colour') Nn1 Nn0 clock frequency 0 0 31.3kHz 0 1 15.6kHz 1 0 7.6kHz 1 1 61Hz to 15.6kHz (frequency generator 0/3)

Table 3. Register description.

(74LS02). A frequency of 8MHz is needed to produce the full range of true musical tones; this said, it does not mean that you cannot experiment!

Being a digital device the SAA1099 operates using PWM (Pulse Width Modulation) techniques to generate sound. This operates at about 62.5kHz; although this frequency is inaudible, it needs to be filtered from the output. This is done to avoid problems with amplifiers. The filter network, composed of resistors R4 to R7

and capacitors C1 to C6, blocks the high frequency component.

The audio amp, IC5, is a TDA2822 stereo amp, providing about 0.6 watt per channel into 8Ω speakers with a 5V supply. This may not sound like a lot but it is more than enough. Each speaker can be of any shape or type, provided that its impedance is 8Ω or greater. SK1, the audio output socket, is a 3.5mm stereo type; it can be used with 'Walkman'-style headphones or extension loudspeakers.

RV1 and RV2 are the individual volume controls, which can also be used to correct the sound balance to compensate for the location of your speakers relative to your ears. RV1 and RV2 should be used to set the maximum level that you (or the family!) can tolerate, the final volume level being software programmable. R14 and R15 are precautionary measures included to ensure that you do not blow your ears off, or overload IC5.

5. What's an Octave?

And now an explanation of the octave system for the musically uninitiated. Each time you go up an octave you double the frequency of the note you are producing, so having produced a tone you can push it up the scale by increasing the value in the Octave register. The standard musical note is 'A' with a frequency of 440Hz but put it up an octave and you have 880Hz, then 1760Hz, then 3520Hz etc. It is very easy to halve or double the frequency of a tone, once you have produced it. Referring again to Table 2, it can be seen that each of the octave registers is split into two 3-bit groups. 3 bits will give you decimal values from 0 to 7, which represent octaves 1 to 8.

Construction

Construction is very straightforward, as all components are mounted on the high-quality double-sided, plated through-hole PCB supplied with the kit. On the component side of the PCB is a silk-screened legend, which is present to aid you in the installation and orientation of components, see Figure 4. The Constructors' Guide supplied with the kit is packed with helpful advice, which is very useful if you are not familiar with kit-building. It is a good idea to mount all of the larger components as close as possible to the PCB – this avoids space trouble, now or later, with any other cards in your PC. For this reason, note that the leads of XT1 are bent through 90° so that the crystal mounts flush against the board. The bending of the wires should be done before the component is soldered in place – and should be done 2mm or so away from its body, so that they do not touch its metal case. Audio output socket SK1 should be mounted as close as possible to the board for mechanical stability – after all, audio

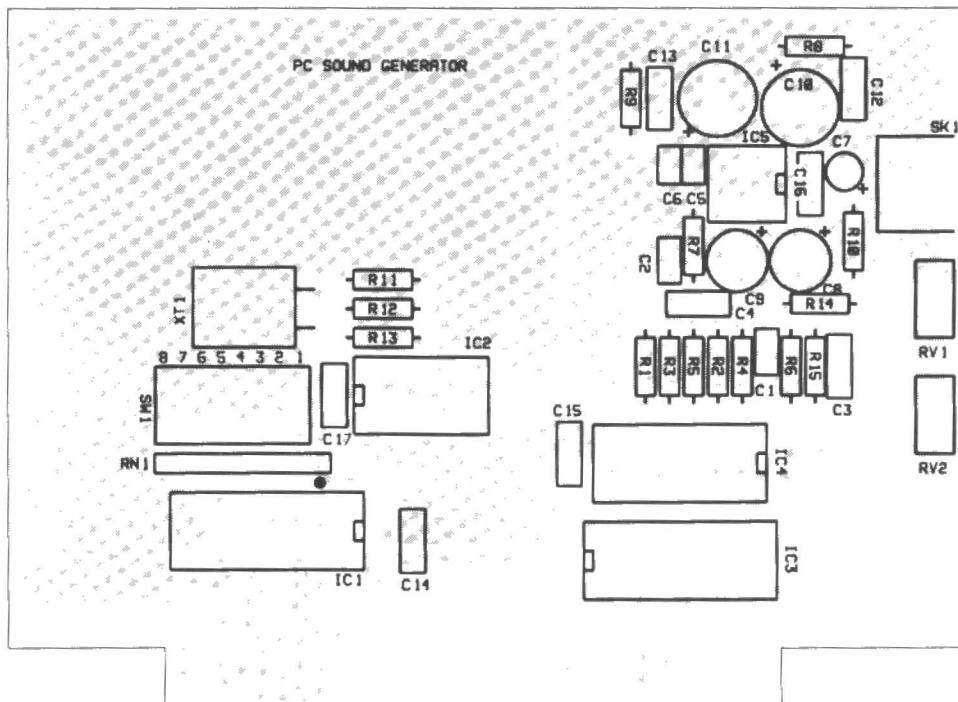


Figure 4. PCB layout and legend.

leads will be plugged into (and unplugged from) it, subjecting the connection to a lot of mechanical force. Note all ICs are socketed; solder the sockets in place, fitting the ICs just before testing. The orientation of the ICs, as with the electrolytic capacitors, is critical – check to see that they are fitted correctly *before* soldering them in place – unsoldering components takes time, and could damage the board and/or components!

As the only real test of the unit is to use it with your PC, please check everything *thoroughly* before you insert the card into your computer and power it up. Any mistakes, and the worst could happen!

With some PCs it may be possible that the amplifier stage, IC5, which is quite sensitive, will pick up noise from other computer components and busses since the sound card will be actually installed inside the computer case, and which will make itself known in the form of background noise. If you find that you have this problem, then an optional metal screen is also available which can be fitted over the amplifier stage area on the top side of the PCB to exclude interference from surrounding circuitry, see Figure 5.

Using the PC Sound Generator with your Computer

Within the PC's I/O map, many locations are used for built-in hardware like the disc controller card, the serial ports, the printer port, timers, floppy drives, and many others. However, there is a space set aside for the user's additional cards; this space of 32 addresses covers 0300H to 031FH. Despite the fact that most cards have their

address fixed (what options are open to you if you want to fit two or more such cards?), the PC Sound Generator has been designed so that it can fit anywhere in this address range. Knowing where your existing card(s) is located, you can place your PC Sound Generator at a different address. If you have two cards both addressed at, say 0300H to 0303H, bus contention is likely to cause problems. For example, one card could pull some data lines low while another card is trying to hold them high, so that the data itself is undefined.

Setting Up the Address Decoding Logic

As we can see from Table 4, A8 to A9 must always be high, while A5 to A7 must always be low. A1(LSB)–A4(MSB), on the other hand, are set according to the final address selected. This, as already stated, is between 0300H and 031FH. A0 is used for selecting internal registers within the SAA1099 device, as in this instance – see Table 1.

Programming the Card

Programming the card is very simple, again a look at the tables shows that it is just a matter of entering the relevant data into the appropriate registers. However, do not forget that some registers are split into 3 or 4 bit

parts, the 4 low bits (D0 to 3) are used for controlling the left hand side, the 4 high bits (D4 to 7) controlling the right hand side.

The simplest form of program is a continuous loop:

```

1 REM PC GW-BASIC PROG
2 CLR : KEY OFF
3 DEFINT A-Z
4 :
10 INPUT "Enter base address", BASE
   REM (300H = 768 Decimal)
20 REGISTER = BASE : BASE1 =
   BASE + 1
30 FOR X = 0 TO 31
40 OUT BASE1, X
50 PRINT "Enter value for register "; X;
55 INPUT VALUE
60 OUT REGISTER, VALUE : REM
   OUTPUT VALUE TO REGISTER X
70 NEXT X
80 GOTO 30
90 STOP

```

Or in Turbo Pascal something like:

```

programme sound;
var
  base,tone,register:integer;
begin
  clrscr; {clear screen}
  writeln('Enter base address');
  4 read(base);

```

A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
H	H	L	L	L	X	X	X	X	X
H	H	L	L	L	L	L	L	L	L
H	H	L	L	L	L	L	L	L	H

= 1100XXXXXX = 0300H to 031FH
 = 0300H = data for registers
 = 0301H = register address

Table 4. Address decoding.

```

begin
repeat
  write('Enter which register');
  read(register);
  port[base+1]:=register;
  write('Enter value for this register');
  read(tone);
  port[base]:=tone;
end;
  until register<0
end.

```

It would be a good idea to initialise an array to hold the current register contents, something like 'DIM TONE(31)' (GW-BASIC), so that when writing a value to a port you also use 'TONE(X) = VALUE'. In this way you will be able to check any register contents with:

```
PRINT "REGISTER "; X; " CONTAINS ";
TONE(X)
```

Or put it all in a FOR/NEXT loop and check them all:

```
10 FOR X = 0 TO 31
20 PRINT "REGISTER "; X;
  " CONTAINS "; TONE(X)
30 NEXT X
```

There is also a formula which can be used for calculating the required output frequency f_O as follows:

$$f_O = 8 \times 10^6 / (17-OX + (1-FX/255))$$

where OX is the octave number (registers 16 to 18, octaves 0 to 5, see Table 2) and FX is the value to put into the frequency register (registers 8 to 13, tones 0 to 5). For example if you chose 5 for OX and 6 for FX, f_O is very nearly 1kHz. For each octave band, each of the eight notes correspond to increments of 8 in the frequency control register (see also Table 3).

5 REM A SIMPLE PROGRAM TO CALCULATE OUTPUT FREQUENCY

```
10 INPUT "Enter frequency required.", F
20 INPUT "Enter octave value (0-7)", O
30 FX = 800000/2(17-O+(1-F/255))
40 PRINT "Frequency is"; FX; "Cycles"
50 END
```

5 REM ROUTINE TO CLEAR ALL REGISTERS

```
10 REM BASE = BASE ADDRESS
15 DIM TONE(31)
20 FOR X = 0 TO 31
30 OUT BASE+1, X
40 TONE(X) = 0
50 OUT BASE, 0
60 NEXT X
70 END
```

Don't worry if you get it wrong, you can do no harm to your computer or the card. It is just a matter of experimenting to produce the sounds you need, and no doubt you will produce many interesting sounds you didn't want along the way. But it is all good fun finding out and that is how it should be. The PC Sound Card should also prove to be a useful tool to anyone musically talented.

Bit	Description		
En7; En5 to En0 (n = 0-1)	7 bits or envelope control En0 0 left and right component have the same envelope 1 right component has inverse of envelope that is applied to left component		
En3 En2 En1	zero amplitude maximum amplitude single decay repetitive decay single triangular repetitive triangular single attack repetitive attack		
En4	0 4 bits for envelope control (maximum frequency = 977Hz) 1 3 bits for envelope control (maximum frequency = 1.95kHz)		
En5	0 internal envelope clock (frequency generator 1 or 4) 1 external envelope clock (address write pulse)		
En7	0 reset (no envelope control) 1 envelope control enabled		
SE	SE sound enable for all channels (reset on power-up to 0) 0 all channels disabled 1 all channels enabled		
RST	Reset signal to all frequency generators 0 all generators enabled 1 all generators reset and synchronised		

Table 5. Envelope control. Note that all rates given are based on the input of an 8MHz clock.

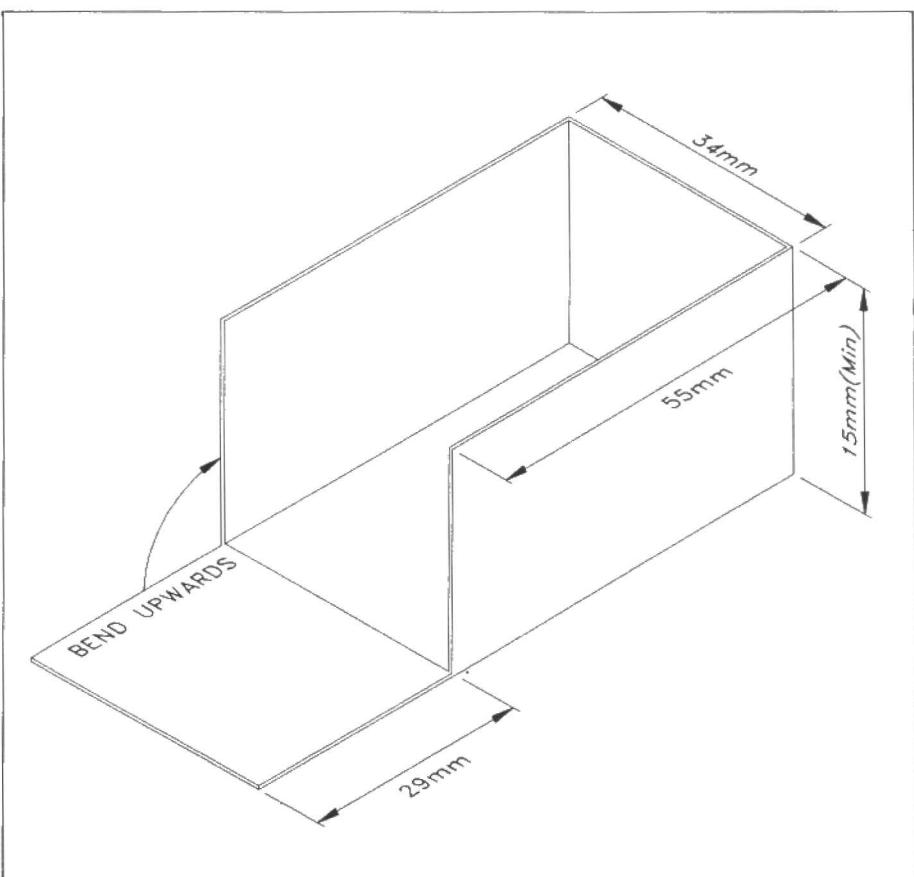


Figure 5. Modifying the optional screening can.

PROJECTING AHEAD

The Life Story
of a Maplin Project

by Martin Pipe

Over the years, Maplin has marketed a vast range of kits and projects suitable for the beginner and experienced constructor alike – so many, in fact, that the 'Projects and Modules' section of the 1993 catalogue contains over 50 pages of goodies for you to build. In this section you will find nearly 200 kits, and it is interesting to note that over 90% of these have been designed by the in-house engineering team. Harking back to 1976, when Maplin was primarily a company involved with electronic music projects, there was only one full-time member of this team. At that time, space was very limited and the first Maplin development laboratory was housed in a rather narrow corridor. Despite this, our original engineer, Dave Goodman, is still happily with the company! Interestingly, those early analogue synthesiser and organ kits co-designed by him (such as the Matineé organ, long since discontinued), are still highly regarded by enthusiasts – witness the adverts in the *Classified* section. Since those early days, Maplin has risen to prominence as a major electronic products distributor (while Dave has risen in position to Development Manager), and the development team has grown in number to six. The names of these engineers will be familiar to 'Electronics' readers who have seen their prolific output – which is increasing still further now that the magazine is published monthly. They all now work in a (thankfully!) much larger laboratory, equipped with the latest equipment, which is located in the same building as the 'Electronics' editorial office.

In the December '89 to January '90 issue of 'Electronics', we published a

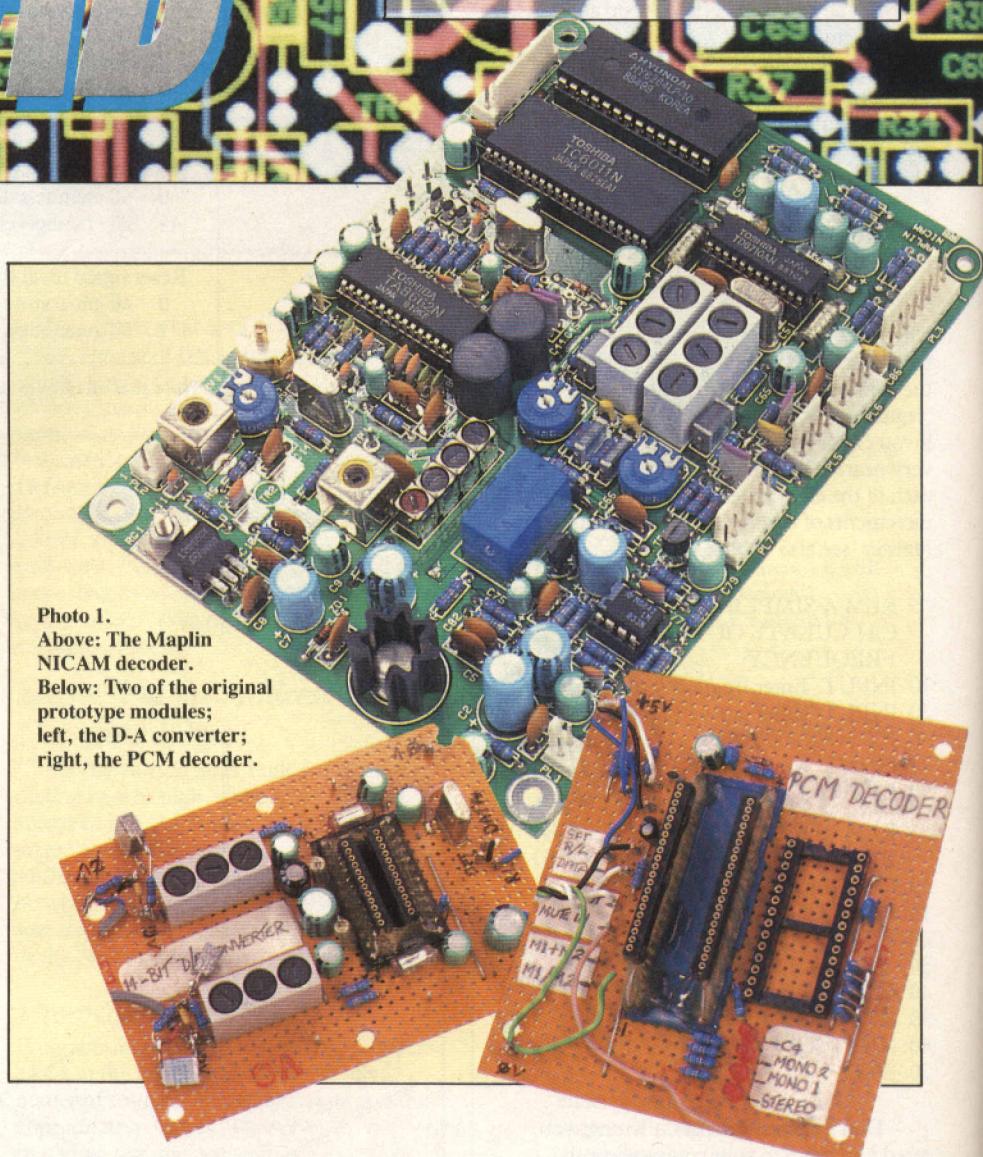


Photo 1.
Above: The Maplin
NICAM decoder.
Below: Two of the original
prototype modules;
left, the D-A converter;
right, the PCM decoder.

design for a NICAM stereo TV sound decoder, which can be used to convert a normal TV set or VCR to give near-CD sound quality. This design, by Chris Barlow, proved to be superior to decoders already fitted in some NICAM-ready equipment, and the kit based around the design rapidly became a best-

seller. The story of this project's conception is a fascinating one, involving many processes and decisions. The purpose of this article is to explain what happens in the months before a design is published in your favourite magazine, and specific reference will be made to the NICAM decoder, which is shown in Photo 1.

PROJECTING AHEAD



Photo 2. The Versatronics VS3000 PCB prototyping system, seen here in the capable hands of lab engineer Nigel Skeels.

A Bright Idea

There are several sources of project ideas. Over half of the designs published in the magazine are developed from the engineers' own ideas (often inspired by manufacturers' data sheets and press releases). Occasionally, a project brief will originate from the marketing department (the NICAM decoder was born in this way). Other ideas stem from suggestions made by Maplin customers; there is a suggestion book inside most Maplin shops, and ideas are welcomed in letters to the magazine. Some project designs (which, wherever possible, must always use components already supplied by Maplin) are sent in by outside parties. Maplin is always interested to hear from those who have such ideas, and in fact some of the most interesting projects of the past few years have originated from our valued customers. The project brief, dating from mid-1988, for the NICAM decoder was "to produce a retro-fit board for existing TVs and VCRs, up-rating them without the need to replace them". In the end, a complete kit was introduced which incorporated a tuner, control unit and the decoder into a smart functional case, and provided an option for remote control. In addition, a new, manufactured (and competitively priced) NICAM tuner unit (see Photo 4) has been introduced into the 'Pro-Sound' range, featured in the 1993 catalogue.

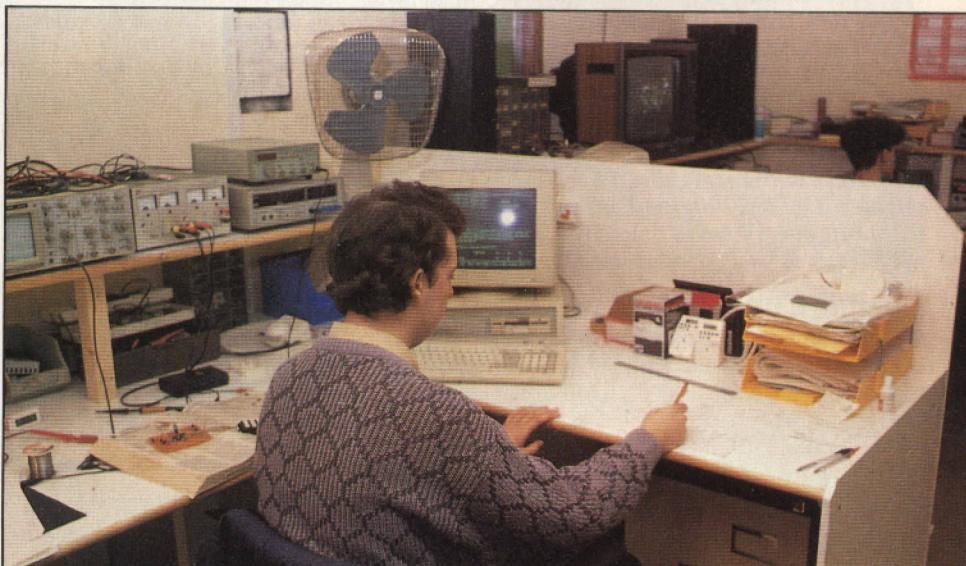
Decisions, Decisions

The engineer will then discuss, with Dave, the potential of the project and its intended market. Every Monday morning, you will find Dave, locked in constructive argument with the Marketing Manager (Vic Sutton) and Magazine Editor (our very own Robert Ball). Here, the viability and marketability of a new idea is discussed. Maplin prefers to 'steer away' from circuits which require

complex alignment, 'biotechnological' projects, radio transmitters and systems which connect directly to BT 'phone lines. Where possible, Maplin kits are designed for use with batteries - or a ready-built mains power supply. If the project meets these criteria and is accepted, it is assigned a 'Project Construction Rating'; a number which varies from 1 to 5. Simple devices are normally given a rating of 1; the value increases with complexity of construction, the level of setting-up and/or alignment required, and any potential hazards inherent in the project (this applies to any mains-powered or other high-voltage kits). These ratings are featured in the relevant section in the Maplin Catalogue. The actual type of project is also determined; i.e. whether it is a 'building block' (Data File) or something which can be used in its own right. The 'Data File' features are



Above: Two of Maplin's lab engineers, Gavin Cheeseman and Nigel Skeels, in the company's development laboratory.



Above: Lab engineer Gavin Cheeseman, at his comprehensively equipped workbench.

interesting, having been introduced comparatively recently. They are normally used to introduce a new device and are essentially an extension of the manufacturers data sheet (as the name suggests). Example circuits are included in these articles, these being intended to 'fire the imagination' of the reader, although the circuits themselves usually find an immediate use in their respective applications.

Having reached an agreement that the project has good potential, the next stage is to decide how to implement it. For example, the chip set to be used in the NICAM decoder had to be chosen. Normal Maplin policy states that, wherever possible, established stock components should be used, this making life easier for the Buying and Stock Control departments – as well as the engineers, who may have to wait patiently for samples of the latest components. However, with NICAM being a new concept at the time, a completely new set of components had to be introduced. After considering the merits of several different chip sets, the Toshiba set was chosen because it was the only complete set on the market at the time (Toshiba appeared to be the only manufacturer to supply the all-important QPSK decoder, which they were not prepared to supply on its own i.e. for use with other manufacturers' chips!). There is always a gamble when designing a project around completely new specialised ICs. Normally, the reliability record of the component has yet to be established, and in some cases the manufacturer may withdraw it, which is hardly good news when a designer has spent many man-hours developing a circuit based around such a device! However, despite this uncertainty the Toshiba design proved to be an excellent choice as even now it provides excellent performance, coupled with high reliability. Indeed, the new GL43W single-board Pro-Sound unit is based around these components. However, the chip set was only a portion of the new components required; other specialised items included the crystals (which had to be cut specially for the design), the 6.55MHz bandpass filter and the two 15kHz low-pass 'hash' filters which follow the digital-to-analogue converter. Fortunately, the three filters required for each kit (and initially the first prototype) were already being manufactured by a Far-Eastern company.

Design Considerations

While waiting for all of the special components to arrive (which, incidentally, took 6 months), the actual circuit began to take shape. The design was based around Toshiba's application circuit, but incorporated several refinements. These included a tuned MOSFET amplifier, prior to the 6.55MHz filter and QPSK demodulator. The purpose of this is to make the unit operable from a fairly low-amplitude NICAM carrier-



Above: One of those Monday morning meetings! From left to right, Vic Sutton (Marketing Manager), Dave Goodman (Development Manager), Robert Ball (Magazine Editor), Roy Smith (Publications Manager), John Dudley (Drawing Office Manager) and Mark Brighton (Customer Technical Services Manager).

level, ensuring compatibility with most TVs and VCRs. This amplifier features a relatively high input impedance, so that it will not significantly load the IF strip of the host TV tuner. In addition, power supply regulators were incorporated so that the unit would run from a single 12V DC supply rail (and ground). These are a conventional series regulator to provide 10V DC, and a 7805 three-terminal device for the 5V DC rail. To ensure a clean supply, each rail is well decoupled and filtered. In addition, automatic and manual sound mode switching arrangements were catered for – enabling the unit to switch automatically between the NICAM signal, and an external input (normally connected to the output of the conventional 6MHz TV sound demodulator, so that regular FM sound can be heard should the transmitter not be broadcasting NICAM programming). Other design work involved two LED function indicator drivers, and an op-amp based circuit for each channel providing a



Above: The 'Electronics' editorial team. From left to right they are Robert Ball, Mike Holmes and Martin Pipe.

Below: The 'Electronics' design and production department. Far more than just names under the editorial(!) They are from left to right, Peter Blackmore, Jim Bowler, Brian Lauezzari, Alan Wright and John Craddock.



slight amount of gain over the audio frequency range, coupled with a low output impedance.

When an initial design has been completed, a list of the parts used is compiled. It is then checked with the Buying Office that existing Maplin-supplied components required for the project are not likely to be discontinued or changed in any way. Such a situation rarely occurs in the case of most general components, but any resulting modifications to a design must be done as early as possible. This is because at later stages in the marketing of the project where, for example, a large batch of PCBs have been produced, such changes will be very expensive (and time-consuming) to implement. Should the circuit be refined later on, the Buying Office is always informed about new or changed components, so that any appropriate action can be taken as soon as possible.

Constructing and Testing the Prototype

By the time the components had arrived, the preliminary circuit design was completed (and probably forgotten about by then!). The various stages (D-A converter, PCM decoder, QPSK demodulator, etc) were each assembled in modular form on pieces of matrix board (this is a pre-drilled SRBP board resembling Veroboard, but with no copper tracks; connections being made with wire or the component leads). Two of these boards are reproduced in Photo 1. Note the home-made IC sockets (Shrink DIP sockets were extremely hard to find then!). And then the moment of truth, what would it perform like? By that time, the Crystal Palace transmitter was running NICAM tests during normal working hours from its ITV and Channel 4 transmitters, so the prototype circuit was hooked up to the IF strip of the workshop TV set, and was powered up. This time we were lucky – it worked first time. For the benefit of you electronics enthusiasts out there, we can safely say that this is the exception rather than the rule! However, a de-emphasis network had to be added just after the 15kHz low-pass filter on each channel. This is because pre-emphasis (to the J17 standard) is applied during the NICAM encoding process here in the UK; it is not normally done in other countries implementing the system (pity, because it does improve the signal-to-noise ratio!), and due to the sparse information available during the development of our decoder, such a filter was not incorporated in the original prototype. The unit was then tried out on several different TV sets and VCRs to ensure that the unit was compatible with them, and any minor circuit changes required were made. The unit was tested over long periods so that any shortcomings in the performance would be brought to the fore, and the necessary modifications implemented.



Above: The Drawing Office – note the PCs used for CAD work. The staff who hold the reins, from left to right are, Tony Bricknell (another of our lab engineers) with Ross Nisbet, Nicola Hull and Paul Evans.

The Drawing Stage

When a project circuit design has been brought up to the high Maplin standards, the next stage is to prepare the various sketches and drawings which will be required. This includes PCB and case artwork, and drawings reproduced in the actual magazine article (such as circuit diagrams). The preliminary artwork prepared by the engineer is sent to the Drawing Office, where it is brought up to the high standards required for publication and PCB manufacture. Over the last three years, artwork has been prepared using CAD (Computer Aided Design) techniques. At present, four PC-based systems are used in the Drawing Office; three running Ranger 2 software (a more advanced version of the Ranger 1

package sold by Maplin) and another installed with AutoCAD. Large high-resolution colour displays are used with these 486-based machines, and a laser printer is used to produce the final computer-generated artwork on a special high quality paper. Up to three years ago, artwork was produced using the manual draughting-film and transfer approach, but the change to CAD has brought about dramatic reductions in the time needed to create artwork. CAD has also introduced other significant benefits. For example, existing diagrams previously generated with CAD are much simpler to modify than manually-created ones. The PCB design of the NICAM decoder was a complex one, making use of a double-sided plated-through-hole board. The

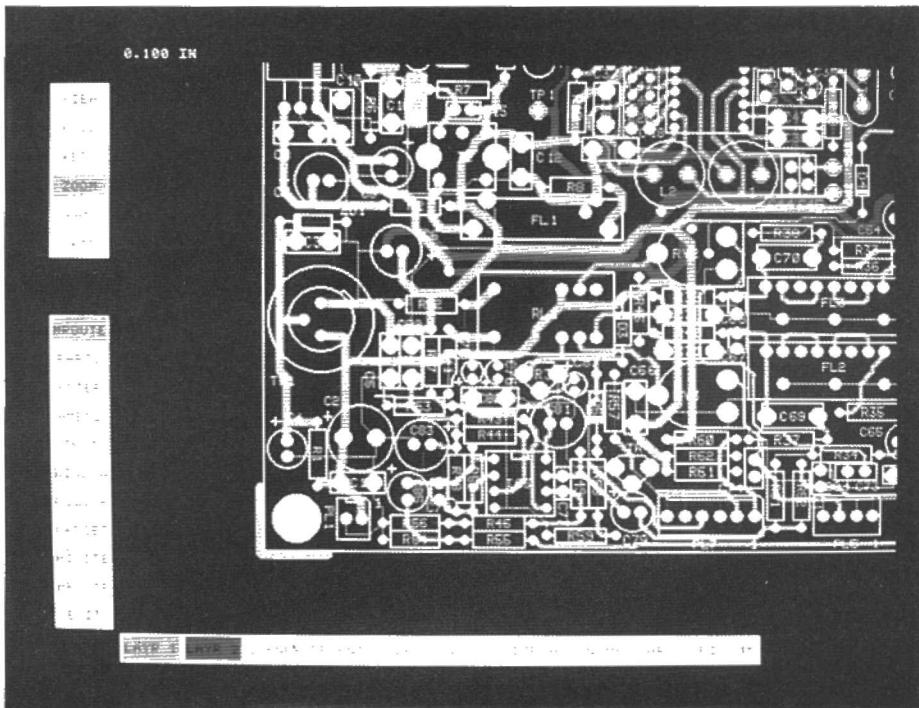


Photo 3. The NICAM PCB as it appears on the Seetrax Ranger 2 CAD system display monitor.

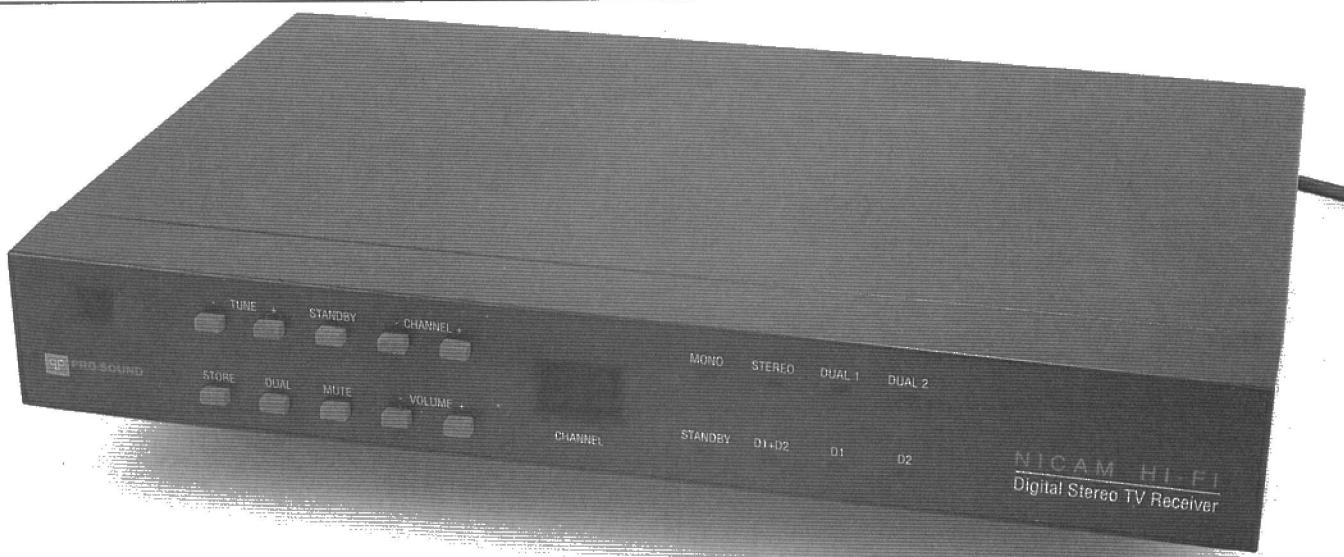


Photo 4. The ready-built remote-controlled Pro-Sound GL43W – a superb example of the latest generation of NICAM tuner unit. It enables you to adapt your existing AV set-up to receive superb stereo TV sound for a modest outlay. In addition to a superior quality colour composite video output (for use with a VCR or monitor), it features a stereo amplifier for the direct driving of loudspeakers.

rough design submitted by the engineer was entered into the CAD system and converted into a form suitable for production. PCB production facilities require designs for all track layers of the PCB (in the case of the NICAM decoder, there were the top and bottom sides), CNC (Computer Numerical Control) drill co-ordinates, the solder-resist layer (a thin film covering the whole PCB area, except for the component solder pads and edge-connector fingers, which helps to avoid solder bridges between tracks causing short-circuits), and the silk-screen pattern which is normally applied to the component side of the PCB, representing the component positions. A CAD screen view of the NICAM PCB, and its various layers, is shown in Photo 3. We can safely say that the industrial-quality glass fibre PCBs used in our kits are amongst the best available, and are superior to most fitted in commercially-available mass-produced domestic electronic equipment. After checking, the NICAM PCB artwork was sent to a PCB manufacturer so that a pre-production prototype could be fabricated.

Since the NICAM decoder was introduced, the Development Lab has invested in a Versatronics VS3000 PCB prototyping system (shown in Photo 2). This PC-controlled piece of hardware features a robot arm which accommodates a special ink pen or a drill. When a PCB design from the Drawing Office CAD suite has been loaded into the host computer, the VS3000 will 'ink in' the PCB track pattern on the copper side of the board; special holes and slots are also catered for. The machine is then set up to automatically drill the board from the co-ordinates supplied by the CAD suite. (although a member of staff is always present to ensure that nothing goes wrong!). After drilling, the boards are etched and tinned in the normal way. In addition to the above, the system will

draw the component legends on the appropriate side of the board. As can be imagined, this £3000 system was a welcome addition to the laboratory's facilities!

When the prototype PCB has been finished, it is inspected and if all is well the project is assembled on it, and subjected vigorously to yet another round of tests. Sometimes, the PCB design needs to be modified and this can happen several times before it is just right. In fact, the NICAM decoder PCB which eventually went into production was Version 3 i.e. the original design had to be revised twice.

Getting it Down on Paper

By now, the design is in a form ready for publishing in our magazine. It has been thoroughly checked, and final parts lists and PCB designs have been prepared. Next comes the stage that the engineers find the most boring (except waiting for components, maybe?) – the writing of the article for (eventual) publication in your favourite electronics magazine! Normally, this is started 6 months in advance; and the finished, checked, article must be ready at least 3 months before the publication date of the magazine. The article normally includes a circuit description, constructional details, instructions for testing and use, and a parts list. To go with this are various diagrams and tables (e.g. connection and assembly diagrams, component drawings, panel artwork and specification tables), required in addition to the final versions of the previously prepared circuit diagram. Any new artwork is sent to the Drawing Office so that it can be brought up to publication standard using their CAD systems.

Much of the information transfer outlined above has been made much easier and quicker by the recent introduction of an experimental LAN, or local

area network. Most of the computers in the Drawing Office, Publishing Department and Development Laboratory have been linked together. Now, PCB designs can be transferred directly to the Versatronics prototyping system, and articles can be sent straight from the Lab to the magazine editor. At the centre of the LAN, is a file server (based around a 386 PC, fitted with a 40 megabyte hard disk), running the Artisoft LANTASTIC 'peer-to-peer network' operating system. A peer-to-peer network is one where individual users (known as 'nodes'), present on the network, can transfer information between one another without depending on the central file server. The file server hardware is the bare minimum required, and will be expanded when the final requirements have been determined. An advantage of a peer-to-peer network, however, is that hardware requirements are minimal, as can be seen from Photo 5. The file server manages the system, and determines which user has access to which files. In addition, it provides an 'inter-user' message facility, and holds a common base of software, which includes the WordPerfect word processor, and a database written specifically for Maplin using Clarion Professional Developer. This database contains information on suggested new products, such as lab inspection reports. The LAN is also installed on the central Maplin mainframe computer, so that users can check stock levels and kit parts lists, in addition to other tasks.

The finished text is submitted to the 'Electronics' editor, Robert Ball, using the LAN. He decides the next available issue in which the project design will be published. The text of the article is checked for cohesiveness and correct grammar by the publishing team, consisting of the editor, technical author and proof-reader, who will amend it if required. The artwork from the Drawing

Office is checked against the engineer's original sketches and, if correct, will be signed and stored with the finalised text ready to be sent to the Production Department, along with the rest of the material for that issue. The Production Department are a creative bunch who are primarily responsible for the graphics and layout that make every copy of 'Electronics' a treat for the eyes - as well as the mind! This particular area of the magazine has also been computerised - Maplin has purchased a DTP (Desk-Top Publishing) system, as used widely by daily newspapers. This makes the tasks associated with producing the magazine a great deal more efficient, so that a greater amount of time is made available for the more interesting and creative aspects of the job. For example, documents and CAD-derived artworks are able to be transferred directly from the LAN and laid out on a monitor screen, which represents the actual magazine page. Artwork (photographs and diagrams) are 'scanned' into the computer with a digitiser, instead of using the current laborious photographic methods. However, at this stage all we can do is to repeat that hoary old cliché: 'WATCH THIS SPACE FOR DETAILS'!

The NICAM decoder project details were published in the December '89 - January '90 issue, although an excellent introductory article about the NICAM broadcasting system (written by Paul Gardiner, an IBA engineer) was published in the previous copy of the magazine. Subsequent issues dealt with designs for the Tuner and Accessory Kits (which provided the remote control, user interfaces - and a nice case to put it all in). However, 'Electronics' interest in TV stereo sound goes back much further, to the June - August '87 issue in fact, with an explanation of the NICAM system, comparing it with existing stereo TV systems. This article was written by J.M. Woodgate, and makes very interesting reading. An interesting fact, and one of which Maplin can be rightly proud, is that these articles are used for reference by several Far Eastern broadcasting organisations and manufacturers.

Getting Kitted Out

A major consideration that requires a great deal of planning and organisation is the fact that the kits must be ready for sale, on the day the relevant magazine article has been published. This means that the right components must be ready before the appointed date, so that the kits can be put together (and in some cases, such as the NICAM decoder, the 'ready-assembled' modules as well), and put into stock. Six months before the design is put into print, Buying Office staff check the finalised kit details previously entered by the Lab engineer onto Maplin's mainframe computer, so that future stock control records can be maintained, and the correct components ordered in the

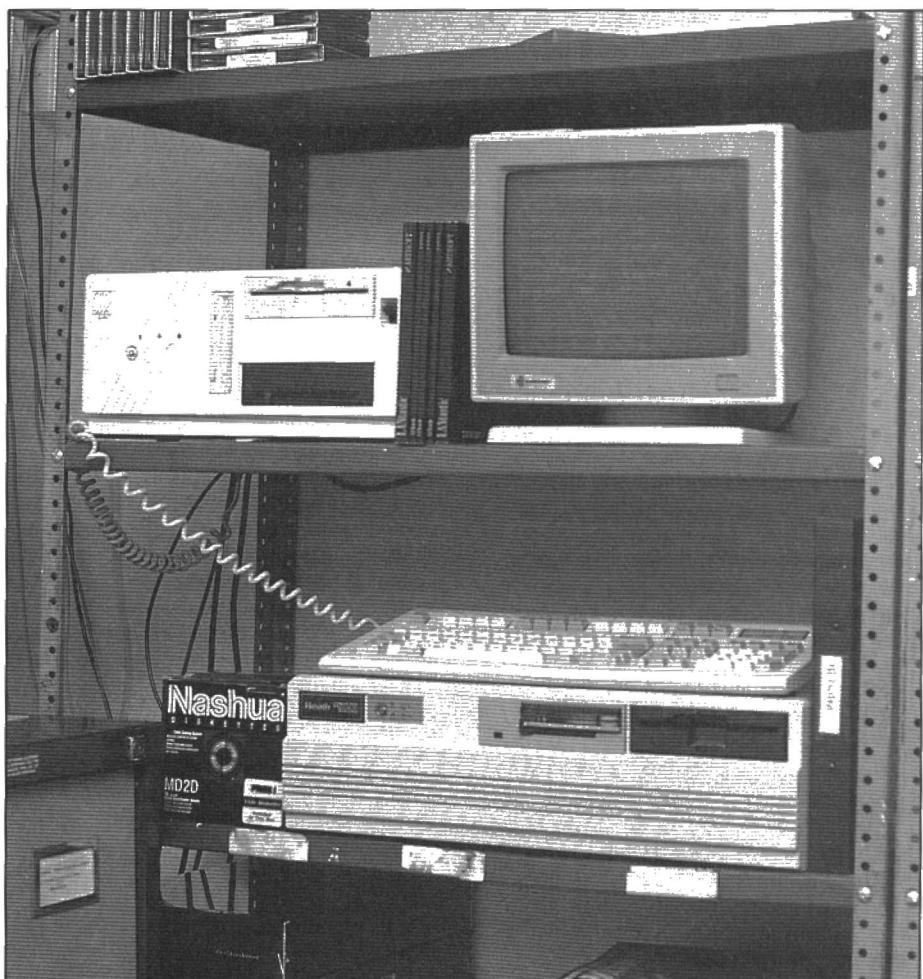


Photo 5. The LAN file server.

correct quantities at the correct time! In fact, this six-month period can be less, depending on whether the kit requires new items to be stocked. As has been seen, the NICAM decoder required several specialised components - and there was a considerable lead time for these (hence the 6 months!) As a result, the NICAM decoder took nearly 2 years to reach the public! Depending on the design, a kit could take as little as six weeks. In addition, the PCB has to be manufactured, and there can be a long wait for these, depending on the schedule of the sub-contractors (PE, located near our new Distribution Centre at Barnsley; and PMS, of Rayleigh in Essex) that we employ for this task.

At this point, most of our work has been done. The magazine is published and sold at the newsagents, or delivered to your door if you have taken out a subscription. The regional Maplin stores are stocked with kits and are bracing themselves for the 'mad rush!' Likewise, a sufficient number of kits are supplied to the Mail Order warehouse to meet the anticipated demand (although we do tend to under-estimate occasionally!). The 'Get-You-Working' division are 'genned up' on the design, so that any avid home constructors who lose their way can be put back on the right track. The next person in this chain is YOU, the reader who will determine whether the kit is a

'hit' or not. The NICAM decoder and its related kits met (and continue to meet) with a great deal of success, with the kit builder and trade customer alike, and this is a true indicator that all the hard work has not been in vain!

The purpose of this article has been to give the reader some insight into the various processes and decisions that are made before a Maplin project goes on sale. As has been seen, it is a fascinating tale, with more to it than meets the eye at first glance. Every electronics enthusiast enjoys building kits; it is not just the end result, but the fact that you have built it yourself and learnt from your experience. You may like to know that each member of the laboratory staff is a hobbyist himself, and derives as much pleasure in designing kits as the Maplin customer does in making something useful that works! In fact, most of the Lab engineers started from building kits themselves. I will leave the last word to Dave Goodman himself: "I would not leave my job for anything!" (Except, perhaps, for a pint of beer! - Ed).

Next Month

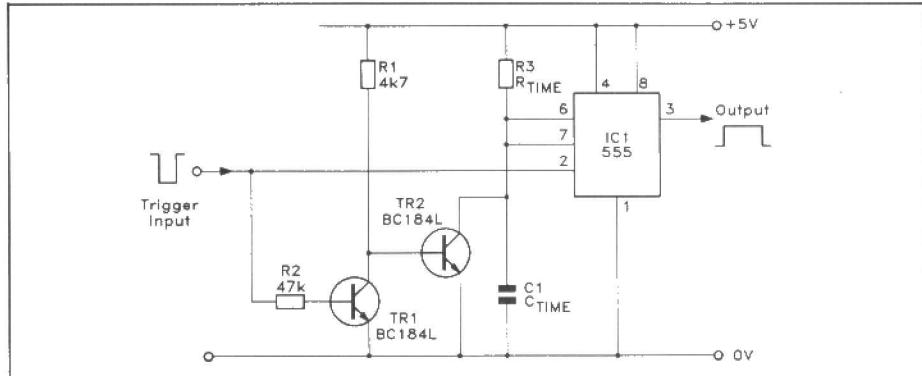
We shall look at how the PCBs supplied with Maplin kits are made. This is a fascinating story in its own right, and to those of you who make your own PCBs at home, it may hold a few surprises!

CIRCUIT MAKER

Circuit Maker is a forum for readers' circuits, ideas and tips. The circuits and information presented here must be considered as a basis for your own experimentation, no warranty is given for suitability in particular applications, reliability or circuit operation. Maplin cannot support, in any way, the information presented here. However, where possible, we will endeavour to check that information presented is correct and that circuits will function as stated. If you would like your ideas to be considered for inclusion in Circuit Maker, please mark your submission 'Circuit Maker' and send it to: The Editor, 'Electronics - The Maplin Magazine', P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Retriggerable 555 Timer by Jonathan Peters

To my knowledge there is no way of building a retriggerable 555 monostable type circuit without resorting to the use of additional external components. My suggested application for this is described as follows. Essentially, the effect is achieved by discharging the timing capacitor each time a trigger pulse is applied, which effectively restarts the timed period.



Circuit diagram of the retriggerable 555 timer.

Circuit Description

In the circuit diagram, pin 6 of the 555 timer IC1 is the IC's normal discharge switch output. However, in parallel with this is TR2, which performs the same function. While the trigger input is high, TR2 is normally off, its base clamped to 0V by TR1.

However, the 555's discharge switch holds C1 to 0V until a trigger pulse is detected, upon which pin 3 goes high, the discharge switch turns off and C1 is allowed to charge via R3 until the threshold level is reached, detected at pin 7. This resets the timer, pin 3 going low and C1 is once more discharged and held at 0V.

The effect of introducing TR2 and associated components is to discharge C1 each time a new trigger pulse arrives at pin 2, which means that the charge on C1 is never allowed to reach the threshold level until trigger input ceases. When this happens, the high period at pin 3 is timed from the end of the last trigger pulse. The

effect is the same as that available with some common TTL monostable ICs, but implemented with a 555.

TR1 and TR2 provide a means for a short duration trigger pulse to be able to discharge C1 effectively, but if C1 is very large, a longer low time for the trigger pulses may be necessary.

PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	4k7	1	(M4K7)
R2	47k	1	(M47K)
R3	As Required*	1	

CAPACITORS

C1	As Required*	1
----	--------------	---

SEMICONDUCTORS

IC1	NE555	1	(QH66W)
TR1,2	BC184L	2	(QB57M)

*Select for required pulse time.

MAPLIN'S TOP TWENTY KITS

POSITION	DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN
1. (3)	TDA7052 Kit	LP16S	£ 4.95	Magazine 37 (XA37S)
2. (5)	1:300 Timer	LP30H	£ 4.95	Magazine 38 (XA38R)
3. (2)	Live Wire Detector	LK63T	£ 4.75	Magazine 48 (XA48C)
4. (4)	L200 Data File	LP69A	£ 4.75	Magazine 46 (XA46A)
5. (1)	MOSFET Amplifier	LP56L	£20.95	Magazine 41 (XA41U)
6. (6)	Car Battery Monitor	LK42V	£ 9.25	Magazine 37 (XA37S)
7. (7)	Courtesy Light Extender	LP66W	£ 2.95	Magazine 44 (XA44X)
8. (8)	IBM Expansion Sys	LP12N	£21.95	Magazine 43 (XA43C)
9. (9)	Vehicle Intruder Alarm	LP65V	£11.25	Magazine 46 (XA46A)
10. (12)	LM386 Power Amplifier	LM76H	£ 4.60	Magazine 29 (XA29G)
11. (11)	Stroboscope Kit	VE52G	£13.95	Catalogue '93 (CA10L)
12. (10)	Mini Metal Detector	LM35Q	£ 7.25	Magazine 48 (XA48C)
13. (15)	MSM6322 Data File	LP58N	£12.95	Magazine 44 (XA44X)
14. (14)	TDA1514A Power Amplifier	LP43W	£19.75	Magazine 40 (XA40T)
15. (13)	Low Cost Alarm	LP72P	£16.95	Magazine 45 (XA45Y)
16. (-)	RE-ENTRY LM3538W Amplifier	LW36P	£ 7.95	Catalogue '93 (CA10L)
17. (-)	RE-ENTRY Partylite	LW93B	£12.45	Catalogue '93 (CA10L)
18. (-)	RE-ENTRY PWM Motor Driver	LK54J	£10.75	Best of Book 3 (XC03D)
19. (18)	15W Amplifier	YQ43W	£ 7.95	Catalogue '93 (CA10L)
20. (-)	RE-ENTRY Rec/Playback	LM80B	£31.45	Magazine 30 (XA30H)

Over 150 other kits also available. All kits supplied with instructions.

The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

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Stray Signals

by Point Contact

The great day to which PC had looked forward in his last jottings, arrived shortly after he penned them. The sales representative of the cable TV company arrived by appointment to provide the details on the telephone service which was now available to cable TV subscribers in our area, as an alternative to BT ("and by the way, here's another free telephone, which you are welcome to keep whether we sign you up or not"). Given that the cable to the house was already installed, the additional cost to install the 'phone line was a mere £15 – less than BT charges for changing a hardwired junction box to the pluggable type – and Nynex were offering to install a second 'phone outlet for free at the same time. So we signed up without further ado, and both the monthly line rental and the cost of calls are lower than BT so we should soon recoup the installation charge.

The kitchen was one of the few places in which PC had not already installed a 'phone outlet so we elected to have our 'free' second socket there, the first being in the hall, alongside the BT box. Having not yet cancelled the BT line, we have at present two lines and two 'phone numbers – unfortunately you can't transfer your old BT number to the cable company's line. We did briefly wonder about keeping both and using the BT line only for incoming 'phone calls, reserving the new one for outgoing calls and the FAX machine. But we can't really justify two lines, and even if we could, it would be better (at £5 plus VAT a month) to have a second cable line. So, as soon as we have informed all our friends and acquaintances of our new number, it really will be "bye bye, BT". Just two days notice suffices for disconnection, and as one pays the line rental in advance, along with the cost of last quarter's calls, the refund should cover the cost of any outgoing calls since the last bill, with maybe even some money to come back.

Following my remarks in *Stray Signals* Issue 49 about hot air balloons, using the plastic bags in which one's suit comes back from the cleaners, BS wrote in from the North of England, recounting his own experiments in that line. He and his son fitted a cross of stiff



wires to hold open the mouth of the bag, fixing a wad of cotton wool moistened with meths to the point where the wires crossed. Their balloon was released outdoors at dusk, and doodled around over the locality at a great height, before finally drifting out over the sea on the evening off-shore breeze, never to be seen again. An apparently harmless experiment, but nevertheless there were unforeseen repercussions, with the local RAF station, the police and even the coast guard being jammed with calls concerning the UFO which everybody had seen!

The following day the local paper was full of it, and BS wisely decided not to repeat the experiment. His interesting letter went on to recount some of his early electronic experiences, which included the construction of a Baird-type televiser using a Nipkow disc, and using it in 1929 to receive Baird's experimental broadcasts. Charlie, the friendly local radio dealer of my youth, did exactly the same, and used his to receive the Christmas panto broadcast, which was Cinderella. I remember him recalling how the definition of the vertically scanned 30 line picture was so poor, that the only thing he really remembered, was seeing the swinging pendulum of a clock in close-up, which appeared at intervals throughout the story.

He gave me a small mains series-wound electric motor with the word 'TELEVISOR' stamped on the frame, all that was left of his pre-war television experiments; this stayed in stock until after I got married, in case it should ever come in useful.

Mrs. PC and I were very hard up initially as I was still a student, and we were very grateful when a kind neighbour gave us a hand-cranked sewing machine, Singer's 1896 patent, no less. It wasn't long before PC married the televiser motor to it, and made a rat-trap contraption of wirewound resistors as a foot-operated speed control. The resistors were strung along a vertical tagstrip, while a piece of springy brass on the end of a spring-loaded pedal rubbed up or down the other side of the tagstrip, all in the very best Heath Robinson tradition. The springy brass was of course salvaged from the top of a 3V battery, of the sort where the other contact was on the side between the two cells: you'll remember (if you're old enough), the sort of battery that was used in bicycle front lamps.

With safety much in mind – now being a married man – the works of the controller were enclosed in hardboard cladding before Mrs. PC was allowed near it. But to no avail, after all this she decided that her manual dexterity was insufficient to manage the machine, "my hands are too small". So PC has been saddled with the job of sewing ever since. Much later, we inherited a proper electric sewing machine, so the Mk I version was left in the loft of our last house when we moved to the present one. I often wonder what became of it. Certainly the new one is much easier to use, and has fancy facilities for hemming, double row and zig-zag stitching etc. etc. Which all comes in very useful, for you see Mrs. PC is only four feet seven inches tall, but mature woman size round, so ready made clothes are impossible to find. The same goes for patterns, so PC has to make those as well. Just a straightforward engineering job really!

Yours sincerely,

Point Contact

The opinions expressed by the author are not necessarily those of the publisher or the editor.

It all looks so involved...the kit of parts for the 10A 30V Laboratory PSU!



10A 30V

Laboratory PSU

Text by Martin Pipe

FEATURES

- * Digital voltage meter: 3 digit 0.1V accuracy
- * Digital ampere meter: 3 digit 0.01A accuracy
- * Output voltage variable from 0 to +30V (Fine adjustment over 1V)
- * Variable current limit from 0 to 10A
- * LED current limit indicator
- * Output short circuit protected
- * Maximum output ripple 0.5V rms
- * Cooling fan for prolonged usage at full power

This extremely flexible laboratory power supply unit (PSU) is capable of sourcing well-regulated DC voltages of up to 30V at currents of up to 8A continuous, 10A peak. As a result, there is a wide range of potential applications for the hobbyist, service department and educational institutions. For example, it is ideal for the testing of prototypes; in addition to the sheer power output available, there is a current-limiting function - ideal for trying out your more delicate circuits. This function, and the robust nature of this unit, makes it an ideal choice for servicing DC equipment (e.g., portable audio and video equipment) and for college workbenches. In addition, this piece of equipment is ideal for the running of CB and amateur radio equipment,

Applications

- * Laboratories and test benches
- * Powering mobile radio equipment
- * Precision charging of batteries

and even the charging of batteries; lead-acid packs in 'constant voltage' mode, and Ni-Cd cells in 'constant current' mode.

Circuit Description

1. Control PCB

(Refer to circuit diagram of Figure 1). IC2 & 3 are μ A723 voltage/current

regulators. IC2 is used to set the output voltage; R6 providing feedback to compensate for the voltage drop across T2, R16, T3 and R31. A fraction of the output voltage determined by R5 and R23 is supplied to IC2 as feedback. IC3 is responsible for current-limiting; its operation is very interesting. A user-set reference voltage (the 'current limit') is derived from the IC3's on-chip reference via RV1/2/3, R18, R27 and R28. This is compared to the voltage developed across R37 to R40 (which are situated between output ground and the reference ground); if it exceeds the user-set reference, then the error voltage produced by IC3 will be sufficient to forward-bias the LED, in doing so it will turn on the current-limiting transistor integral to voltage regulator IC2.

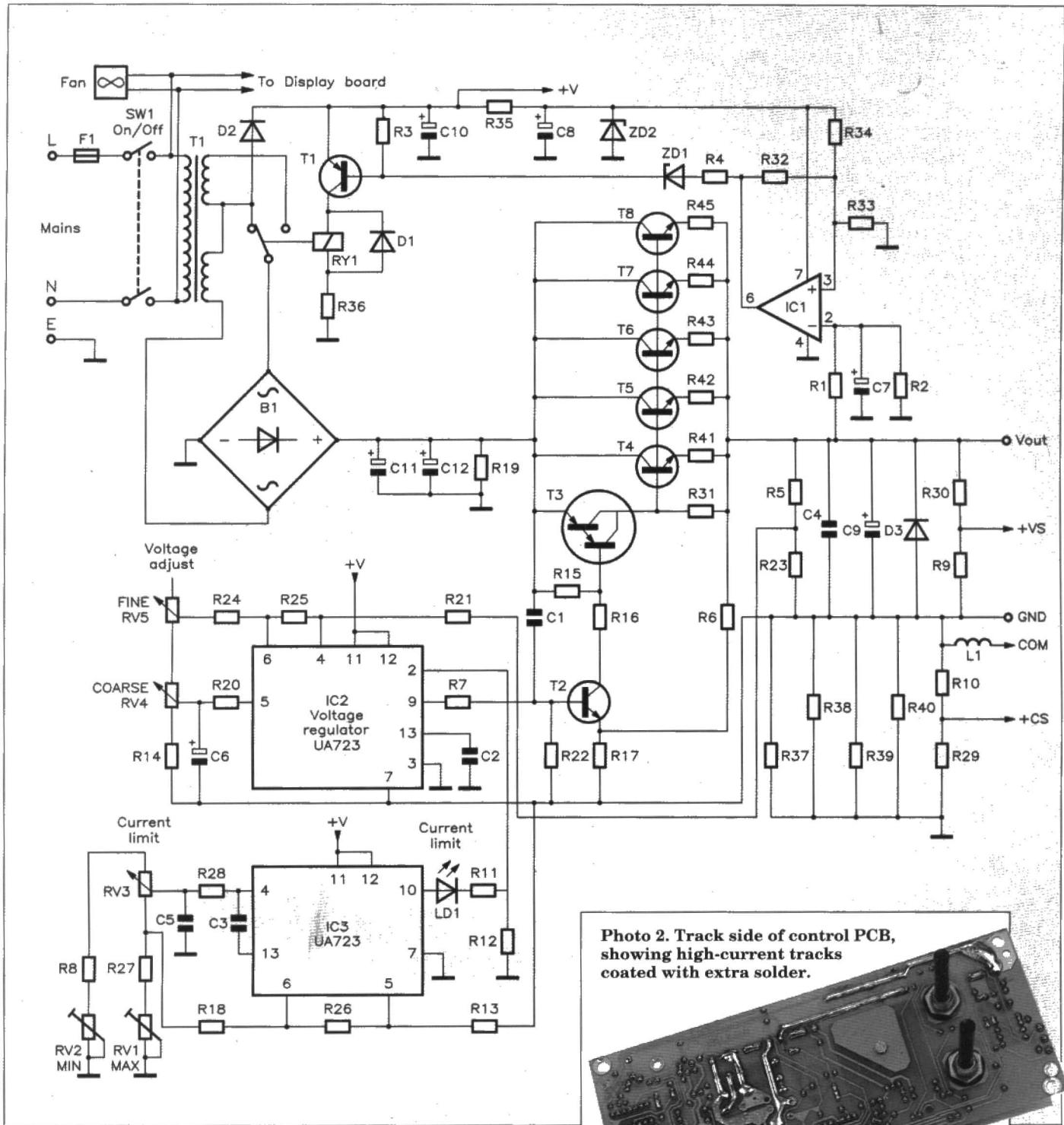


Figure 1. Power supply unit circuit diagram.

T2 is the control transistor for T3, a Darlington device, which provides plenty of drive current for the output pass transistors T4 to T8, which are fed with the smoothed DC output from the bridge rectifier and reservoir capacitors. Note that the main power transformer is a very beefy (300VA, 15-0-15V) toroidal type. R41 to R45 are required to allow for the variation in current gain among the transistors; these items are not matched. D3 is present to protect the power supply from any reverse-polarity voltages that may accidentally be applied to its output terminals.

IC1 is a 741 Op-amp configured as a comparator; it switches in the second winding of the toroidal transformer, via T1 and RY1, when the output voltage rises above 12V; this

Photo 2. Track side of control PCB, showing high-current tracks coated with extra solder.

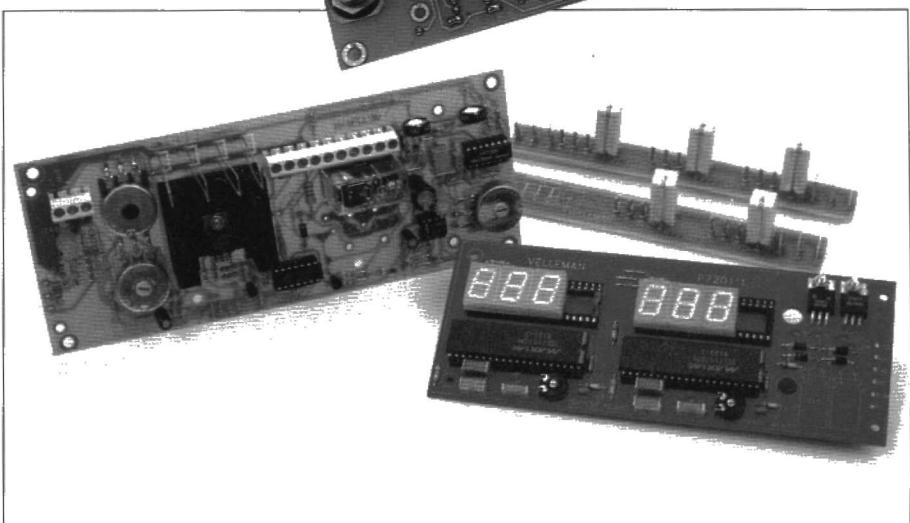
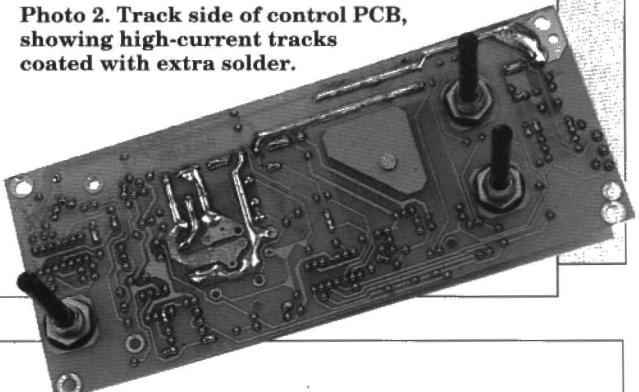


Photo 1. The four assembled PCBs of the Laboratory Power Supply.

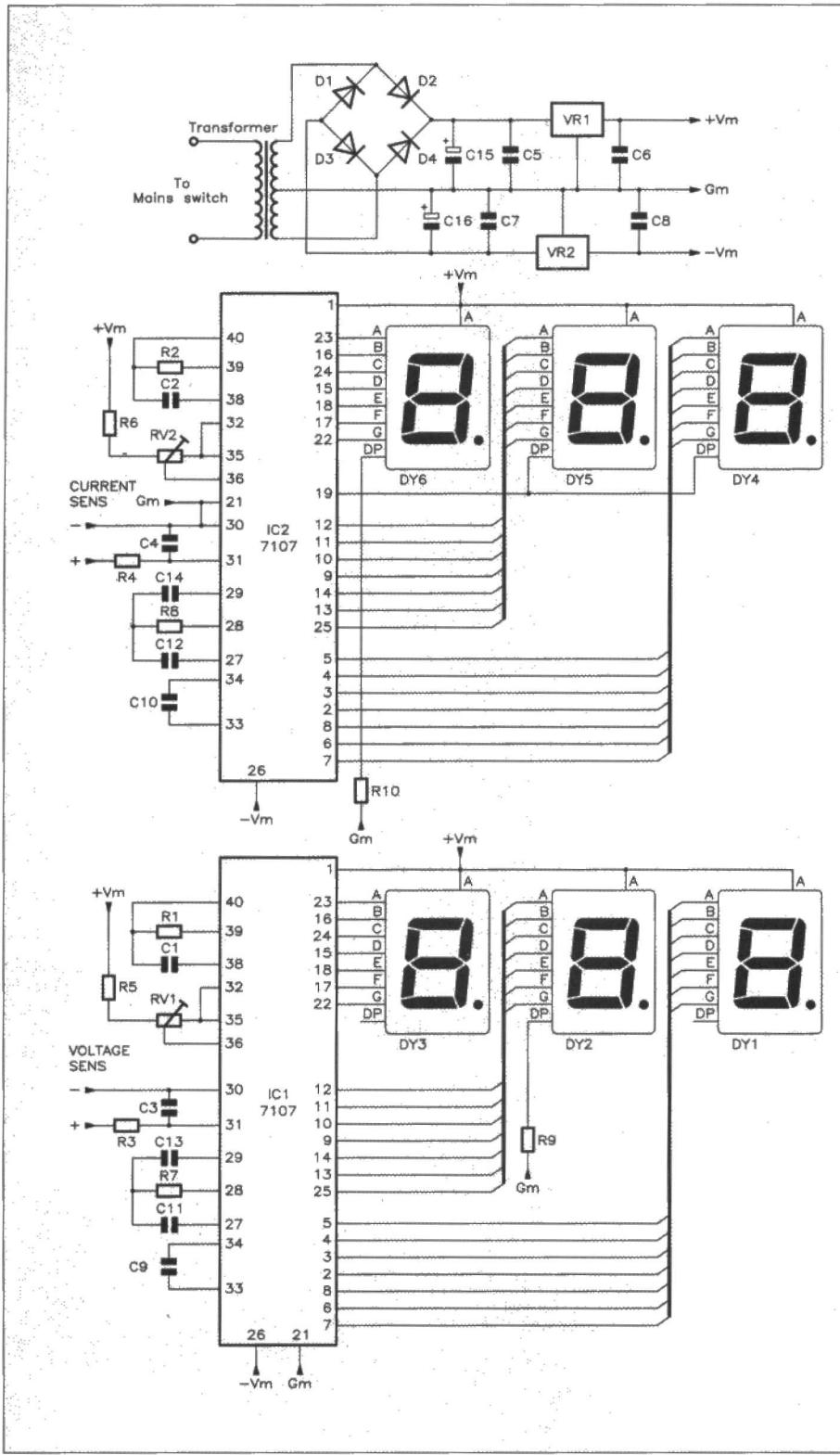


Figure 2. Display circuit diagram.

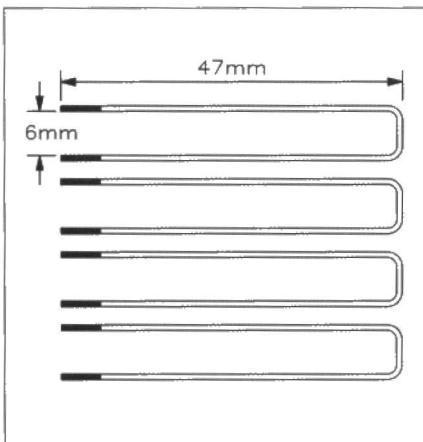


Figure 3. Forming R37 to R40.

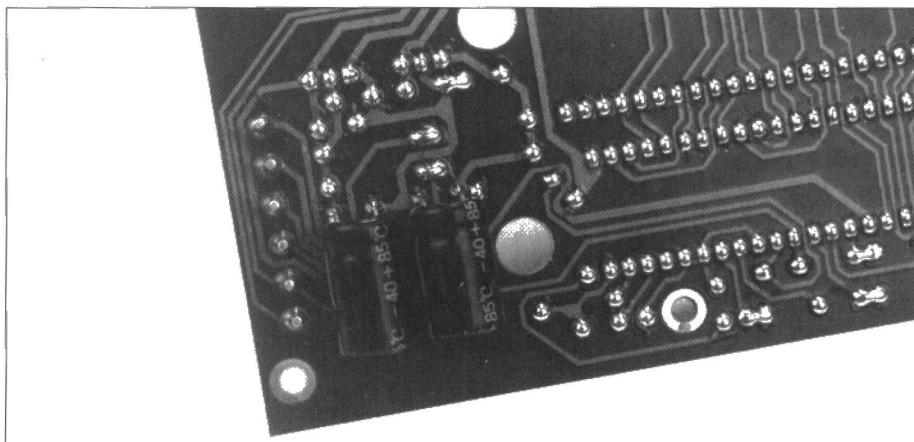


Photo 3. C15 and C16, shown fitted on solder side of PCB.

voltage is determined by R1/R2.

+VS, +CS and COM are (respectively) the positive voltage sense, positive current sense, and common outputs for the display PCB.

2. Display PCB

(Refer to circuit diagram of Figure 2). IC1 and IC2 are complete digital voltmeters, containing all the necessary analogue-to-digital converters and 7-segment display driver/buffers, requiring only a few additional components to function. The display PCB is powered from a split rail (-5V) supply by VR1/VR2 and associated components. Note that the power supply for the display PCB is derived from a separate transformer. IC2 is used as an 'ammeter'; in reality, it measures the voltage (via potential divider R10/R29) that the measured current produces across shunt resistors R37 to 40.

PCB Construction

Construction of the four PCBs (shown in Photo 1) is fairly straightforward, and instructions are given in the manual supplied with the kit. The most important things to watch out for are misplaced components; it is important that you check the orientation and positioning of a component before soldering it in; desoldering is time-consuming and could lead to damage of the component or board. In particular, watch out for polarised components (such as electrolytic capacitors).

When building the PCBs, there are a few points to watch out for:

1. Main PCB

Before fitting RV3, 4 and 5 to the PCB, shorten their shafts to 30mm using a hacksaw to cut off the excess length. Note that these potentiometers should be securely installed on the PCB BEFORE making connections to the PCB with tinned copper wire. The same applies to T3; this item (a BD646 transistor), along with its heatsink, should be bolted to the board before soldering its leads in place. To aid the transfer of heat, heatsinking compound (not supplied in the kit) should be smeared onto the tab of the transistor before mounting it. Note that all three ICs on this

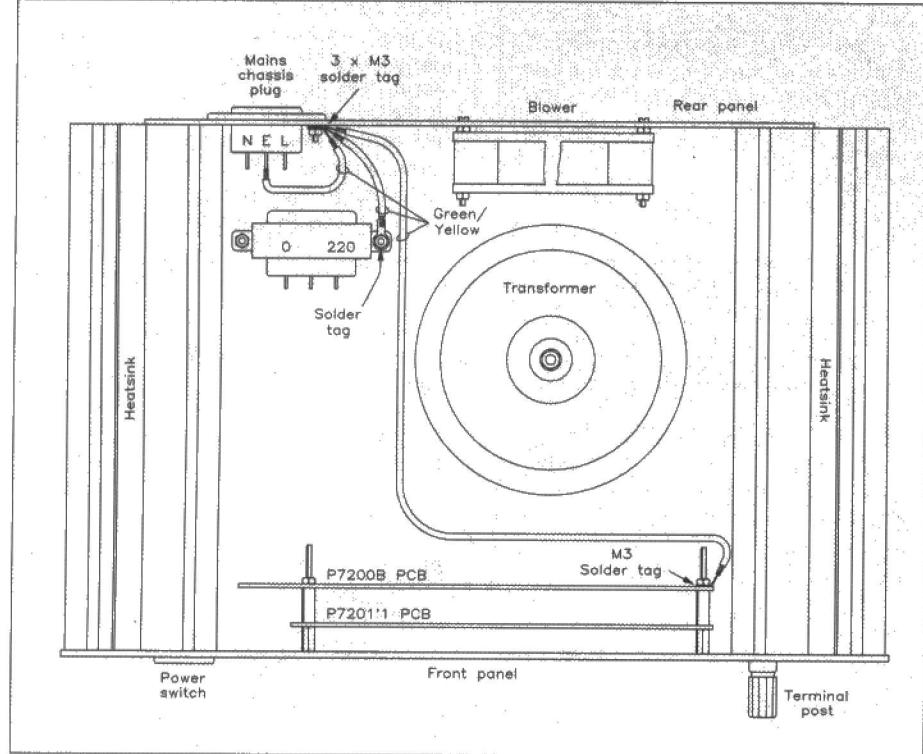


Figure 4. Earthing arrangements.

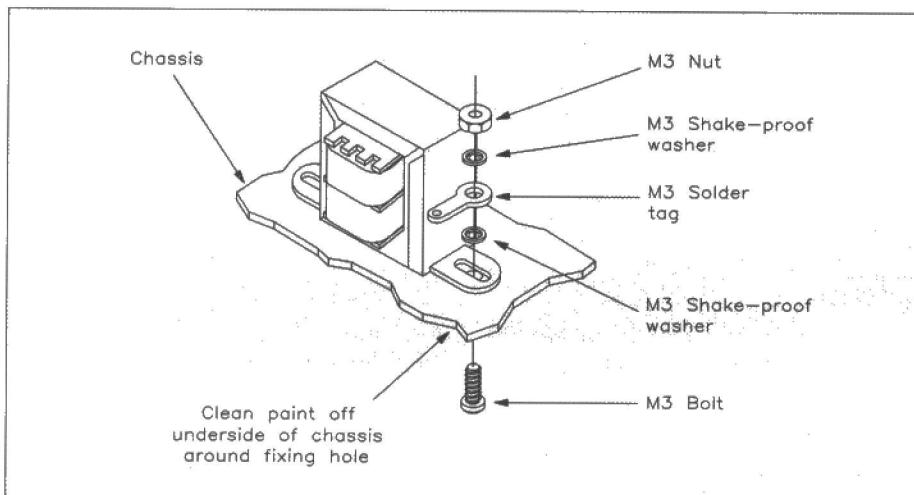


Figure 5. Display transformer

board are socketed. R37 to R40, the shunt resistors, are made from nichrome resistance wire supplied in the kit. Each is formed from a 10cm length of the wire, as shown in Figure 3. The next point to bear in mind is that the current limit indicator needs to be installed on the TRACK side of

the board, so that the LED's tip protrudes 30mm above the board's surface. Note that the two-pole screw connectors J1 to J5 (used to connect the transformer's secondary windings to the PCB) clip together (start with J1) before fitting and soldering in place. After soldering the relay in

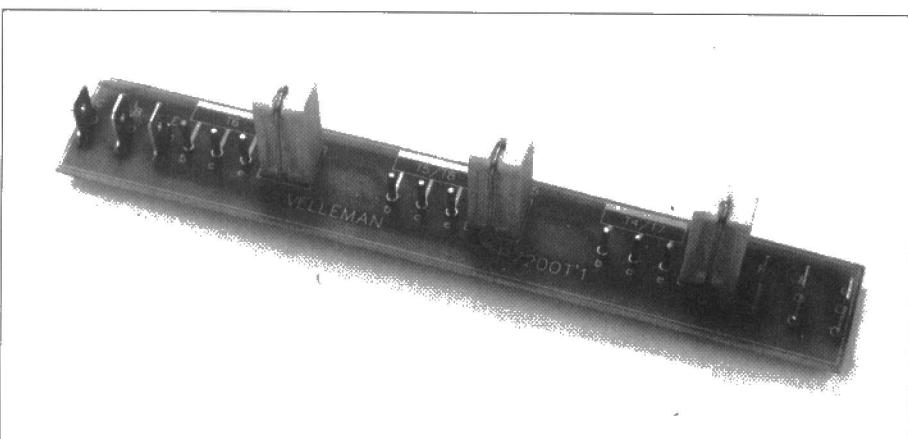


Photo 4. Emitter resistors, fitted vertically to one of the pass transistor PCBs

place, coat the already plated tracks with more solder (see Photo 2), so that they can cope with the potentially high currents expected.

2. Display PCB

Note that IC1 and IC2 are socketed. In addition, the 7-segment displays are also fitted in sockets – ensure correct polarity when finally fitting these in place. VR1 and VR2 should be bolted into place before soldering them to the PCB. Two electrolytic capacitors (C15 and C16) must be fitted to the SOLDER side of the board, paying special attention to polarity – see Photo 3.

3. Regulator Transistor PCBs

Two boards, which fit in the side-mounted heatsinks of the power supply, hold the connections to the TIP3055 transistors (T4 to T8) and their emitter resistors. The two supplied PCBs are identical; however, one should be made to accommodate the connections to two transistors only. On this board, the space marked 'T6', and the adjacent holes for 'Lucar' terminals (1/4 in. blade terminals), should be left unpopulated; the space on this PCB directly above on the heatsink is reserved for the bridge rectifier. Do not solder the transistors directly to the boards – fit PCB pins in the appropriate positions (marked b, c and e). The corresponding emitter resistors (R41 to R45) should be fitted vertically to the board, as shown in Photo 4. Finally, mount the 'Lucar' terminals, and solder into position.

After completing assembly of the boards, check your work thoroughly. Spotting any mistakes before powering up, could save any (possibly expensive!) problems later on.

Mechanical Assembly

Detailed assembly instructions for the case are given in the comprehensive manual supplied with the kit. Assembly is straightforward, but a few remarks made here will save trouble later.

Care should be exercised when installing the regulator pass transistors T4 to T8. These, as already mentioned, are connected via PCB pins to two boards located in the unit's side-mounted heatsinks. To fit, slide the boards into the heatsinks (the correct way up and around – the outline of the transistors is screen-printed on the board to aid you). Looking from the front of the unit, the two-transistor board is fitted to the left heatsink, while the other is fitted to the right one. The transistors are screwed to the heatsink using M3 hardware (an insulating washer and heatsinking compound must be used for each device!), and are then soldered to the corresponding PCB pins. Note that heatsinking compound is also used when attaching the bridge rectifier to the left heatsink. As you can see from the photographs, these two heatsinks form the sides of the case.

When installing the fan, ensure that the arrow, embossed on its side, points to the back of the unit's case. This indicates the airflow direction; in other words, the air is being sucked through the power supply. Air comes in from slots stamped in the top and bottom lids of the case – air flow requirements should be borne in mind when using the finished unit. Do not obstruct the ventilation grilles. Note that the fan should be orientated so that its leads appear at the top. It is fixed to the rear panel with 35mm bolts; if these are overtightened, the

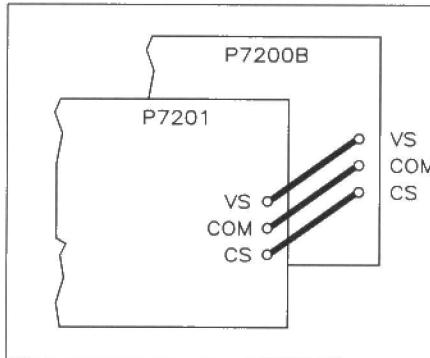


Figure 6. Inter-board wiring.

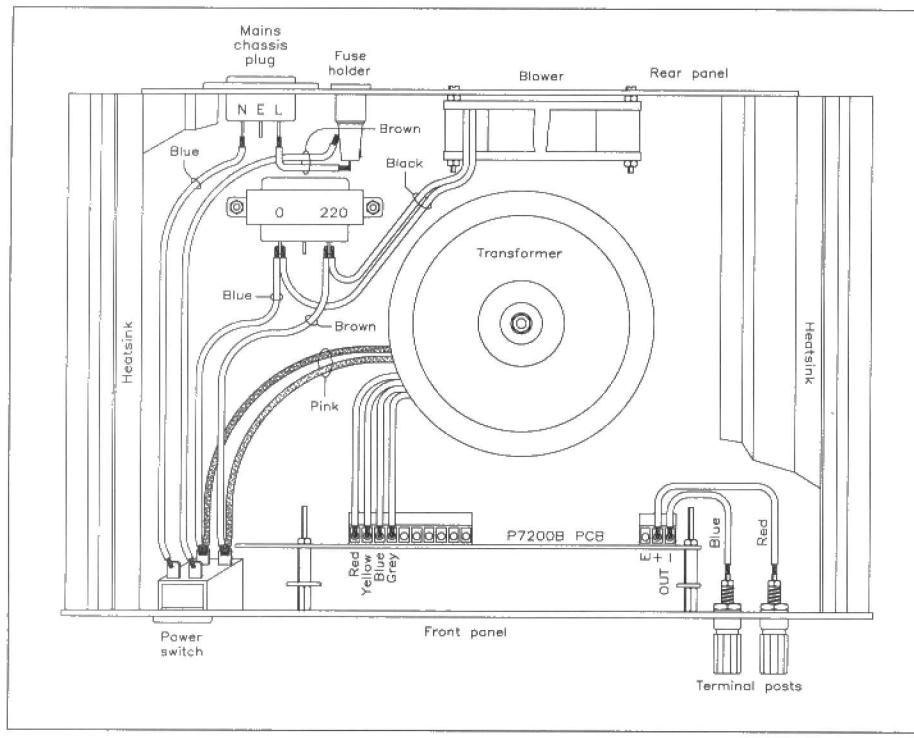


Figure 7. Wiring diagram – mains and PSU transformer secondary winding.

fan's housing could crack. 'Finger tightness' plus half a turn should be sufficient.

The mains chassis plug and fuseholder are the next items to be installed on the rear panel. These are mounted using zinc-plated M3 bolts. Sleeving (not supplied in the kit) should be used to cover all mains connections; insulating boots are available for the chassis plug and fuseholder – see Optional Parts List. Note the earthing arrangements; as shown in Figure 4, one of the PCB mounting posts, the power supply case and the display transformer are all connected to earth. M3 solder tags are used for the bolted components. Note that the paint *must* be scraped away around the chassis plug's screw hole, on the inside of the back panel, to ensure a good earth connection.

The same applies to one of the display transformer mounting screws on the underside of the power-supply; this item should be fitted as shown in Figure 5.

The two main PCBs are attached to the main panel by four 45mm long countersunk M3 bolts. The paint around the top-right M3 hole should be removed; this will eventually form an earth connection. The bolts are

held in place on the other side of the panel by threaded hexagonal spacers. These should be fully tightened, as the screw-heads themselves will eventually be covered by the front panel label. After this has been done, the display board can be inserted over the bolts; if fitted correctly, the display should protrude through the cut-outs. The display board is followed by four non-threaded spacers, and then by the control PCB. The shafts of the control potentiometers should protrude through specially-drilled holes in the display PCB and front panel. The boards are finally held in place by M3 securing nuts. The top right screw must be earthed using one of the tagged leads from the rear panel (see Figure 4). When this has been done,

Specifications

Output voltage	Range: 0 to 30V DC
Fine Output control	Range: 1V
Ripple:	0.5mV RMS (max.)
Voltmeter resolution:	0.1V
Output current:	0 to 8A continuous (10A peak)
Ammeter resolution:	0.01A
Current limit indication:	LED
Power consumption:	300W (max)
Dimensions:	330mm (W) x 90mm (H) x 215mm (D)

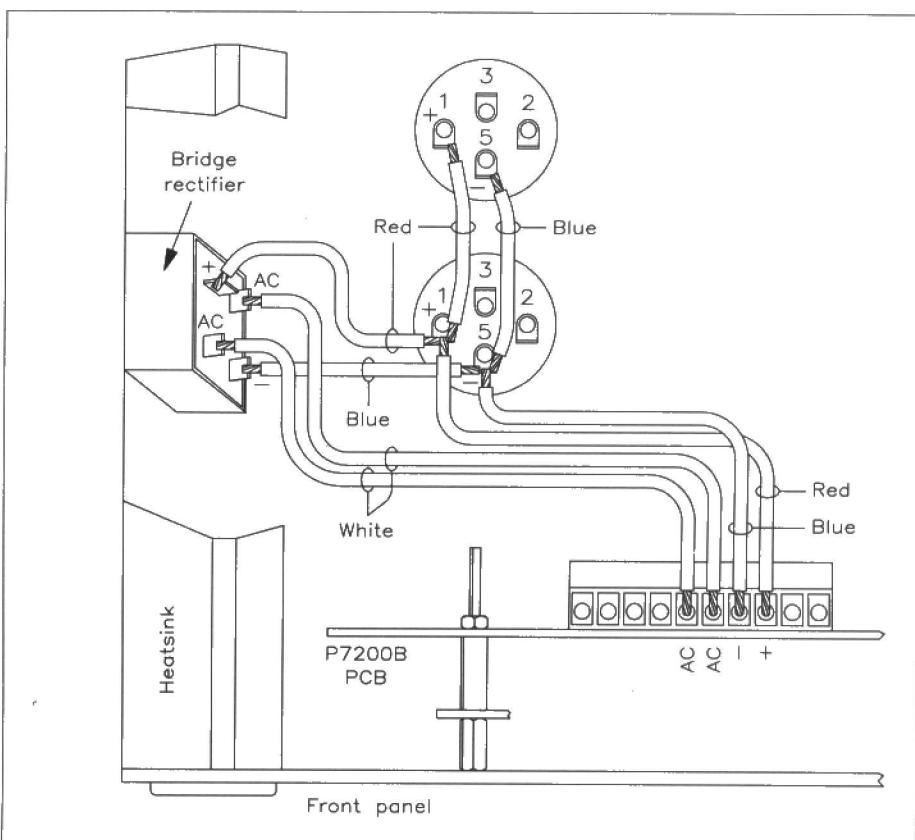


Figure 8. Connection of reservoir capacitors and bridge rectifier.

the three control knobs can be fitted as shown in the photographs. Finally, three connections must be made between the two boards; see Figure 6.

Wiring Notes

Please *disregard* Figure 6.2 of the construction guide supplied with the kit, as this does not include earthing arrangements, and shows only a single-pole switch. A replacement wiring diagram is shown in Figure 7. Please follow the revised circuit diagrams of Figures 1 and 2, rather than

the versions printed in the manual. For safety reasons, Figure 1 incorporates a double-pole mains switch. For clarity, Figure 7 shows only the mains wiring and that of the toroidal transformer's secondaries. Earthing arrangements and the reservoir capacitor wiring are shown in Figures 4 and 8 respectively. For the same reason, the display transformer's secondary wiring has been omitted from Figure 7; it is shown in Figure 9. Earthing apart, output terminals and the display transformer's secondary should be wired up first, as these may

prove difficult to get at once the other wiring has been completed. At this stage, do not connect the fan, or the pass transistor PCBs (shown in Figure 10); this will be done during the testing stage. Connections at mains potential should be covered with heat-shrink sleeving, for safety's sake. The wires to the front-panel mains switch are attached via 'Lucar' receptacles – don't forget those insulating boots! As seen in Figure 7, the primaries of both transformers are connected to the mains switch; extra care should be taken when connecting two wires to each terminal.

Testing

Before testing, you should thoroughly check your work for any problems, such as short circuits, solder bridges, missing or misplaced components.

The following tests involve procedures to be carried out with the case top removed and 240V AC mains connected. It is imperative that every possible precaution is taken to prevent electric shock. 240V AC mains CAN KILL!

Initial testing involves wiring a 240V 40W lamp bulb across the mains fuseholder; do not fit the fuse in the fuse holder at this stage. The bulb is now effectively wired in series with the transformer primary winding. If the lamp should illuminate brightly when mains voltage is applied, then too much current is being drawn by the power supply, which indicates a fault (for example, the primary winding could be short-circuited). If the lamp is permanently unlit, there is likely to be an open-circuit on the primary winding of the transformer. If all is OK, the bulb will light for a short instant, and then go out again (or illuminate dimly) – as a surge of current flows through the transformer. If this does not happen, or one of the other symptoms is noted, then you should investigate the problem further.

With RV1/RV2 (main board) set to their mid-positions, and the current limit potentiometer turned all the way to the right, testing can begin. When the power supply is switched on, the digital displays should now light up. A voltmeter connected between the output terminals should give 0 to 30V when the voltage adjustment control is advanced from left to right. At around 12V, the relay should 'click', indicating that the other secondary winding of the unit's transformer has been switched into circuit.

Turn off the power (and unplug the unit!), then turn the display presets (RV1/RV2, display PCB) fully clockwise. Connect up the pass transistor PCBs, as shown in Figure 10. After switching the unit back on again, check that the voltage can be adjusted as before. Switch off and disconnect the mains supply; the lamp can now be disconnected, and a 4A fuse fitted to the fuseholder. At this stage, the fan can be wired up – see Figure 7.

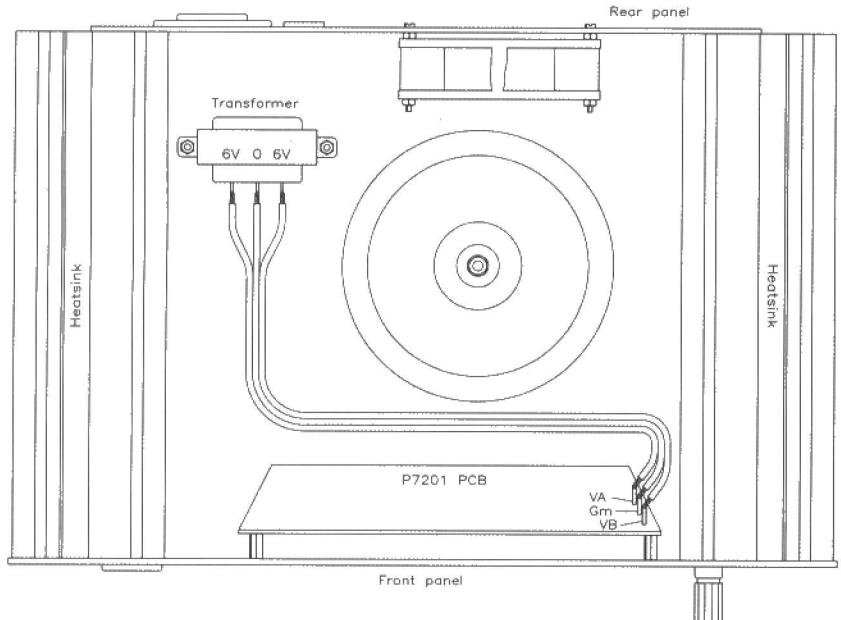
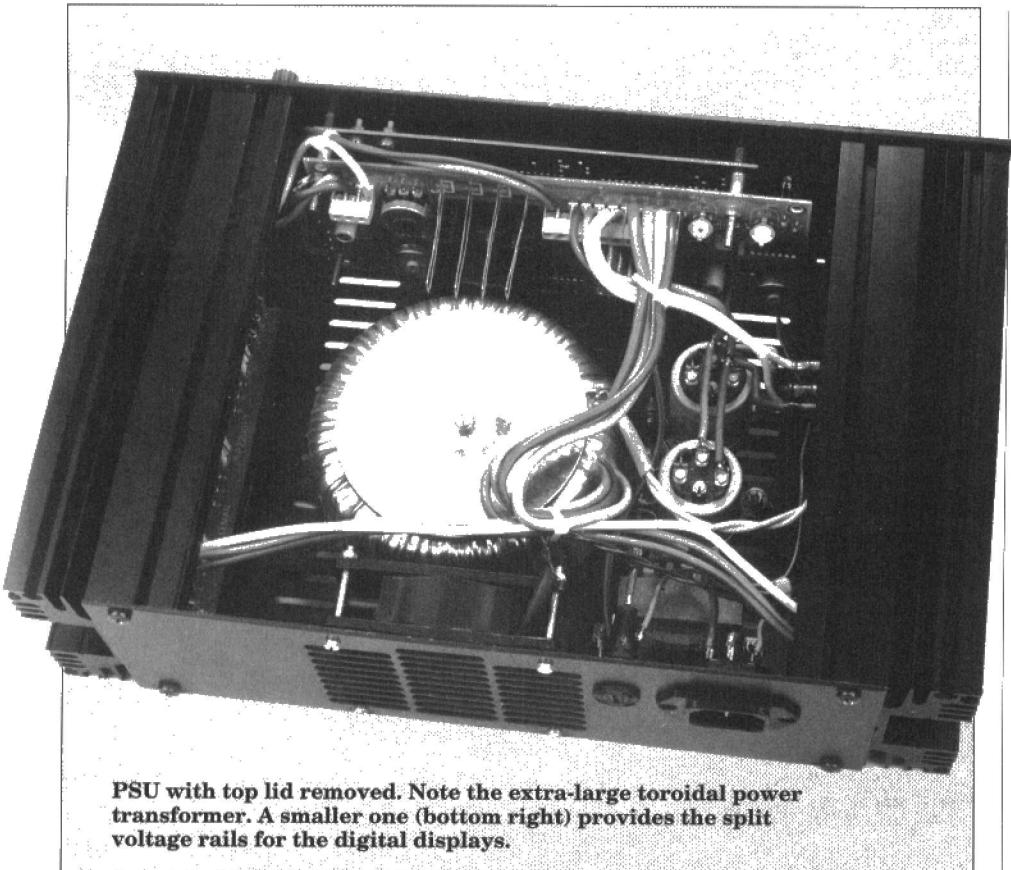


Figure 9. Display transformer



PSU with top lid removed. Note the extra-large toroidal power transformer. A smaller one (bottom right) provides the split voltage rails for the digital displays.

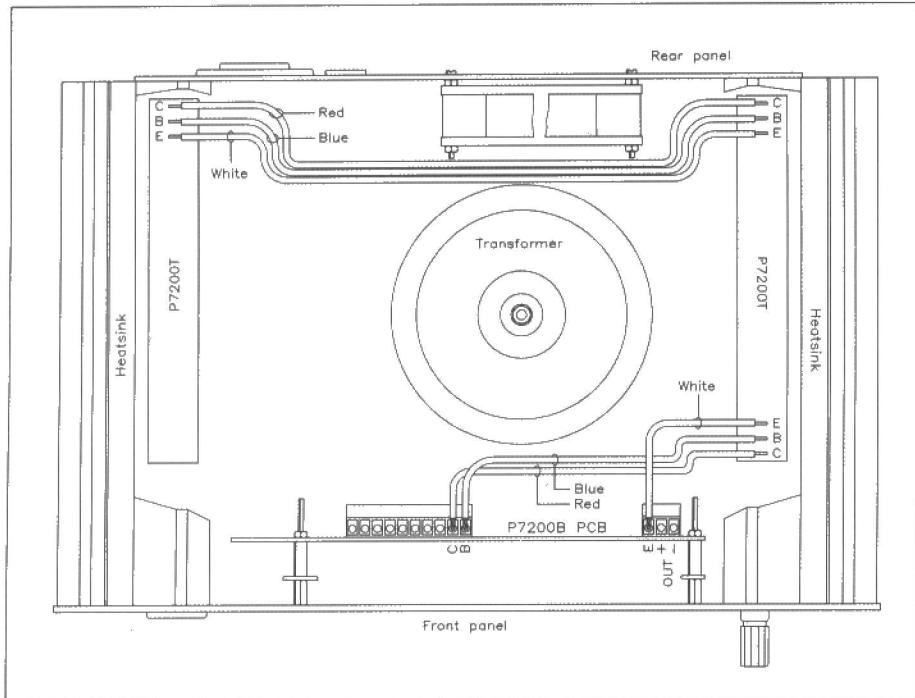


Figure 10. Wiring of pass transistor PCB.

Setting Up

The following procedures should be carried out very carefully and not rushed. The performance of the project is dependant on the accuracy of these adjustments.

Power Supply Alignment

With the unit disconnected, turn the front panel current limiting control

fully clockwise, and the two voltage controls (fine and coarse) to their midway positions. The two presets on the main panel need to be adjusted again; RV1 (maximum current adjustment) needs to be turned fully anticlockwise, while RV2 (minimum current adjustment) needs to be turned fully clockwise. Alignment can now proceed; for this you will need an ammeter (i.e. multimeter set to measure current)

with a range of at least 10A. This should be connected across the power supply's output terminals. After powering up, the 'current limit' LED will light up (the low resistance of the ammeter presents a virtual 'dead short' to the PSU). RV1 should now be adjusted until the meter reads 10A. Disconnect the meter, and turn the voltage/current limit adjustment controls fully anticlockwise. RV2 should now be adjusted until the current limit LED lights up dimly.

Calibration of Digital Displays

After connecting a multimeter (set to 30V range or higher) to the unit's output terminals, set the current limit control to 1A. Switch on (both displays should read 000) and adjust the voltage controls so that the meter gives a reading of 30V. Adjust the (voltage) 'meter adjust' preset (RV1 on the display PCB, accessible from the front panel) until it reads the same as the multimeter. Turn the unit off, and set the multimeter to its 10A (at least) current range. After switching the unit back on again, the current limit control should be set so that the multimeter reads 8A. Adjust the (current) 'meter adjust' preset, RV2 on the display panel, until the unit's display reads the same as the multimeter. Access to RV2 can also be gained from the front panel.

Your power supply is now ready for use!



The completed 10A 30V Laboratory PSU.

10A 30V LABORATORY PSU PARTS LIST

1. CONTROL PCB

RESISTORS

R1	6k8	1
R2	8k2	1
R3-8	4k7	6
R9-12	220Ω	4
R13,14	2k2	2
R15,16	2k7	2
R17,18	820Ω	2
R19-22	22k	4
R23,24	1k2	2
R25	100k	1
R26	15k	1
R27	100Ω	1
R28,29	1k	2
R30	220k	1
R31	18Ω	1
R32	270k	1
R33	12k	1
R34	27k	1
R35	39Ω	1
R36	180Ω (1/2 W)	1
R37-40	Constructed from resistance wire	1m
RV1	100Ω Vertical Preset	1
RV2	47k Vertical Preset	1
RV3	4k7 Pot Log	1
RV4	10k Pot Lin	1
RV5	1k Pot Lin	1

CAPACITORS

C1	150pF Ceramic	1
C2	33nF Metallised Polyester Film	1
C3	68nF Metallised Polyester Film	1
C4	100nF Ceramic	1
C5	1μF Metallised Polyester Film	1
C6,C7	10μF 35V Electrolytic	2
C8,C9	100μF 35V Electrolytic	2
C10	470μF 35V Electrolytic	1

SEMICONDUCTORS

IC1	741	1
IC2,IC3	μA723	1
T1	BC557B (or equiv.)	1
T2	BC547B (or equiv.)	1
T3	BD646	1
D1-D3	1N4000 Series Diode	3
ZD1	10V 500mW zener	1
ZD2	18V 1.3W zener	1
LD1	Red LED 3mm	1

MISCELLANEOUS

L1	4m7H	1
RY1	Single Pole Changeover Relay	1
J1-J5	2-way PCB-mounting Terminal Block	5
J6	3-way PCB-mounting Terminal Block	1
	PCB Pin	3
	14-pin DIL socket	2
	8-pin DIL socket	1
	PCB	1
	Heatsink for BD646	1
	Screw M3 x 12mm	1
	Nut M3	1
	Shakeproof Washer M3	1

2. DISPLAY PCB

RESISTORS

R1-R4	100k	4
R5,R6	22k	2
R7,R8	47k	2
R9,R10	470Ω	2
RV1, RV2	1k Horizontal Preset	2

CAPACITORS

C1,C2	100pF Ceramic	2
C3-C8	100nF Resin-dipped Ceramic	6
C9,C10	100nF Metallised Polyester Film	2
C11,C12	220nF Metallised Polyester Film	2
C13,C14	470nF Metallised Polyester Film	2
C15,C16	1000μF 16V Electrolytic	2

SEMICONDUCTORS

IC1,IC2	7107	2
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VR1	7805	1
VR2	7905	1
D1-D4	1N4000 Series Diodes	4
DY1-6	7 Segment Display (Common Anode)	6

MISCELLANEOUS

40-Pin DIL socket	4
PCB Pin	3
PCB	1
Screw M3 x 12mm	2
Nut M3	2
Shakeproof Washer M3	2

3. PASS TRANSISTOR PCBs

RESISTORS

R41-R45	220mΩ 5W	5
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SEMICONDUCTORS

TIP3055	5
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MISCELLANEOUS

Blade Terminal 1/4 in.	9
PCB Pin	15
Mica Washer	5
Insulating Bush	5

4. HARDWARE

MISCELLANEOUS

B1	Bridge Rectifier	1
C11,C12	4700μF 63V Electrolytic Capacitor	2
SW12	Pole Mains Rocker Switch	1
F1	20mm Panel-mounting Fuseholder	1
	20mm Fuse 4A	1
	Chassis-mounting Europlug	1
	Europlug Lead	1
TRANSFO	Display Transformer (6-0-6V)	1
TRANSFO1	PSU Main Transformer (15-0-15V 300VA)	1
	Mounting hardware (for above)	1 set
	Cooling Fan	1
	Red Terminal Post	1
	Black Terminal Post	1
	Blade Receptacle 1/4 in.	17
	Blade Receptacle Insulating Boots 1/4 in.	4
	Heatsink	2
	Front panel	1
	Front panel foil	1
	Control knob	3
	Rear panel	1
	Base	1
	Top Lid	1
	Electrolytic Capacitor Mounting Bracket	2
	Rubber foot	4
	Zinc-plated Bolt M3x12mm	12
	Zinc-plated Countersunk Bolt M3 x 12mm	2
	Hex. Head Bolt M3 x 15mm	6
	Zinc-plated Bolt M4 x 25mm	1
	Black Bolt M4 x 25mm	4
	Black M4 Countersunk Bolt M4 x 25mm	4
	Zinc-plated Bolt M4 x 25mm	4
	Zinc-plated Bolt M4 x 45mm	4
	Spacer M3 x 15mm	4
	Solder Tag M3	5
	Washer M3	6
	Shakeproof Washer M3	20
	Nut M3	28
	Threaded Bush M3 x 12mm	4

OPTIONAL (Not in Kit)

13A Nylon Mains Plug	1	(RW67X)
3A Fuse	1	(HQ32K)
Insulating Boot for Fuseholder	1	(FT35Q)
Insulating Boot for Chassis Plug	1	(JK66W)
Heat Transfer Compound	1 syringe	(FL79L)
BC Lampholder	1	(FQ02C)
40W Mains Lamp Bulb	1	

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available in kit form only.

Order As VF14Q (30V 10A Laboratory Power Supply Kit)
Price £239.95. H

Please Note: Some parts, which are specific to this project (e.g. PCBs, front panel, transformers etc.), are not available separately.

CIS FOR SOLAR CELLS

by Stephen Waddington

The oil shortages in the seventies heralded a time when the Earth's largest energy resource would no longer provide the continual power requirements previously assumed. Dwindling coal stocks and reduced gas fields emphasised the need for alternative energy sources. Nuclear fuel was thought to hold all the answers, and then, despite increasing amounts of government support and initial promises of an energy source too cheap to meter, people the world over are realising that nuclear fusion does not (as yet) live up to the expectations first proclaimed. Proponents of alternative energy sources have until recently been deemed eccentric, however, the birth of wind farms and recent advances in solar research have provided an illustration of what can be achieved.

Previously dismissed in Great Britain, perhaps because of an apparent lack of sunlight hours, solar energy is now gathering a distinguished following. Several working groups have recently been established to evaluate the potential of solar power, and a flurry of papers published in the technological press reveals that the scientific community is awakening to the value of photovoltaic cells.

Interest

It is now thin film, photovoltaic cells which occupy the minds and laboratories of academic scholars. The essential feature of such cells is that they are created from thin polycrystalline layers formed upon an inert substrate. A comparatively new material, which lends itself to such a form, now threatens to oust other materials as the obvious choice for solar cell construction.

Although silicon is the second most abundant element within the Earth's surface, notoriously high manufacturing costs, coupled with competition for the precious material exploited by the electronics industry, has rendered silicon solar cells too expensive.

Both silicon and gallium arsenide solar cells exist in single crystal form. Manufacture is both time consuming and cost intensive, leaving many critics to doubt the benefit of such devices as viable energy sources. Growing the crystals takes a long time and, consequently, single crystal cells must be employed in active use for a considerable period of time before initial costs are recovered.

Design

Whilst more traditional photovoltaic cells utilise either silicon or gallium arsenide, advances in physical device research indicate that more effective materials are available. Copper Indium Selenide (CIS) has emerged as one of the most promising solar technologies. Being polycrystalline, it is likely that CIS solar cells could be fabricated both in large volumes and at a cost low enough to compete with conventional bulk power generation schemes. The physical depth, a slim 1 to 10 microns, is two orders of magnitude below that of its single crystal predecessors.

Theoretically, the technology could be extremely lightweight, though of course the need for a supporting substrate increases both physical mass and thickness. Current research chooses a substrate of glass, which although inexpensive, is far from lightweight. Deposition of cells onto thin plastic is desirable, though current fabrication techniques prevent such a possibility. This is because, in general, all fabrication methods involve some form of high temperature deposition, or post-deposition annealing. Scientists talk about flexible 'solar blankets', providing a transportable power source which can be almost folded in two - ideal for use in space or remote locations. Such a position may be attained if the advances made in the past decade continue.

Construction methods for the deposition of CIS thin films are numerous. The most reliable and widely used is the

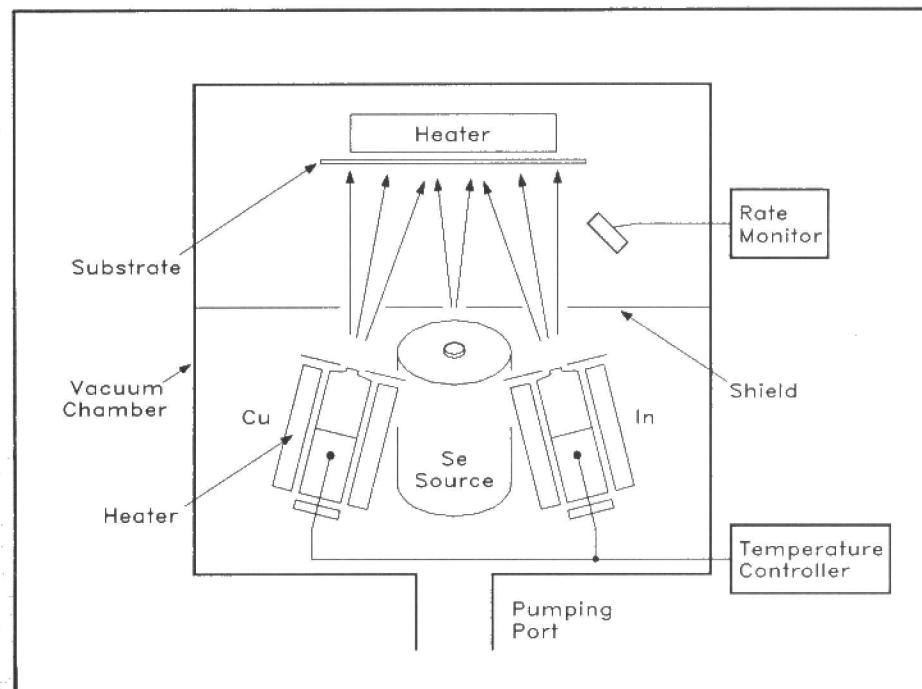


Figure 1. Schematic diagram of a three-source evaporation system for CIS.

'three source evaporation' process. The three elementary materials, copper, indium and selenide, are evaporated onto a substrate. Flux rates are meticulously controlled to produce the film composition required. Figure 1 provides an illustration of a typical system. Research persists into other fabrication methods which include sputtering, selenisation and screen printing, in order to identify a method which could be suitably scaled for manufacturing purposes. Full-scale production would demand guaranteed consistency, uniformity over a large area and cost-effective products.

at wavelengths in the infra-red region of the electromagnetic spectrum, coinciding with the areas where the sun's rays have greatest intensity. These values occur outside of the visible light area of the electromagnetic spectrum, emphasising the fact that, unlike other solar technologies, CIS does not necessarily require bright sunlight. Additionally, a high absorption coefficient increases the likelihood of optimum power output even under ambient light conditions. One school of investigation is exploring the possibilities of overlaying cells with an optically transparent film. Coated with a

hensive terms, as much energy falls on the planet in one hour as its total population uses in a year. Clearly, it would not be possible to cover the entire surface of the planet with photovoltaic cells. Such figures do, however, prompt reflection on the amount of energy which could potentially be secured. Realistically, estimates must be much lower; factors such as cloud absorption and scattering reduce the intensity of the sun's rays. Furthermore, the solar radiation reaching a particular surface is made up of some direct radiation, some diffused (by water droplets and dust particles) and some reflected (by surrounding objects). Figure 3 shows the typical distribution of the sun's rays using the example of photovoltaic cells laid on the roof of a house. In discrete terms, the amount of radiation that one square metre of horizontal surface in the United Kingdom receives during the course of a year is between 800 and 1000 kWh. As established earlier, about 10 to 14% of that could be translated into usable electricity using CIS based solar cells.

Applications

Areas of application for photovoltaic technology are diverse, ranging from a demonstration 6MWp power station in California, to consumer goods which include calculators and battery rechargers. More significant are the products already in use in the Third World. Lighting systems, UHF transceivers, refrigeration for medical supplies and sterilisers are all solar based schemes currently utilised in medical centres throughout Africa. Indeed, it could be said that, in many ways, the 'developing' world has been used as a testing ground for many solar technologies. Predominantly silicon based, many projects failed in the initial stages prompting a bad press, but it is hoped that CIS will form part of a

Material	Current	Predicted
Silicon (Si)	18%	19.5%
Gallium Arsenide (GaAs)	21.4%	22%
Copper Indium Selenide (CuInSe ₂)	14%	20%

Table 1. Projections for future device efficiency.

Efficiency

With its astonishing efficiency for the conversion of electromagnetic rays to actual electrical energy, CIS holds the thin film world record of 14% for a small cell. More typical values are perhaps 10 to 12% for larger devices. Table 1 compares the relative efficiencies of silicon, gallium arsenide and CIS. Although the currently attainable values for both of the traditional materials appear superior, it must be remembered that these are *single crystal* substances, and their high scores provide little compensation for the problems of manufacture.

Whilst silicon and gallium arsenide both achieve efficiencies close to their predicted values, CIS falls short of academic expectation, for numerous reasons. Whilst material scientists have extensively documented the physical characteristics and nature of both silicon and gallium arsenide, CIS does not as yet enjoy such technological comprehension. In addition, thin films are liable to efficiency losses due to the effects of both grain and structural disorder.

Most exciting, perhaps, are the results which indicate that CIS is radiation resistant. Unlike most other solar cell materials, CIS has the proven capability of withstanding long periods in harsh radioactive environments. Recently published material reveals that trial cells mounted on a satellite showed no detectable signs of degradation after a three year period while exposed to cosmic radiation. Remarkably, the cells were completely bare, lacking even the protective glass cover usually employed to make the lifetime of a solar cell long enough to be worthwhile. By comparison, the lifetime of both silicon and gallium arsenide cells are finite, and rather ironically, it is continual exposure to ultraviolet light that causes them to breakdown.

Electrical Characteristics of CIS

Spectral response measurements show that greatest conversion efficiencies arise

monolayer of charge-transfer dye to sensitise the cell, it is thought the film will aid 'light harvesting'.

A typical current/voltage (I/V) curve is provided in Figure 2. Plotted for a model cell exhibiting a 10% efficiency, voltage is shown on the horizontal x-axis, while current density in milliamps is along the vertical y-axis. Devices exhibiting greater than 10% efficiency for the conversion of solar radiation have a short-circuit current density which is typically between 35 and 41 mA cm⁻², with a corresponding open-circuit voltage of 420 to 510 mV.

Energy for the Future?

Theory aside, what of the actual potential? Figures chronicled in meteorological reference books suggest that 10¹⁸ kilowatt hours (kWh) of solar energy reaches the earth each year, or, in more comprehen-

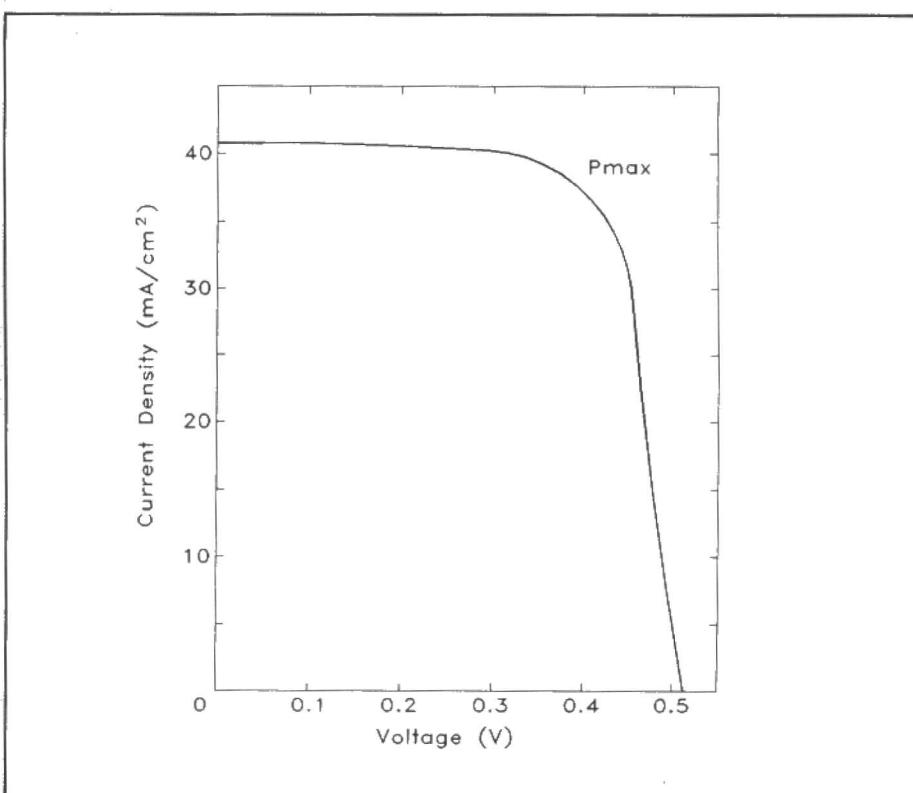


Figure 2. Current/voltage plot for a typical CIS cell.

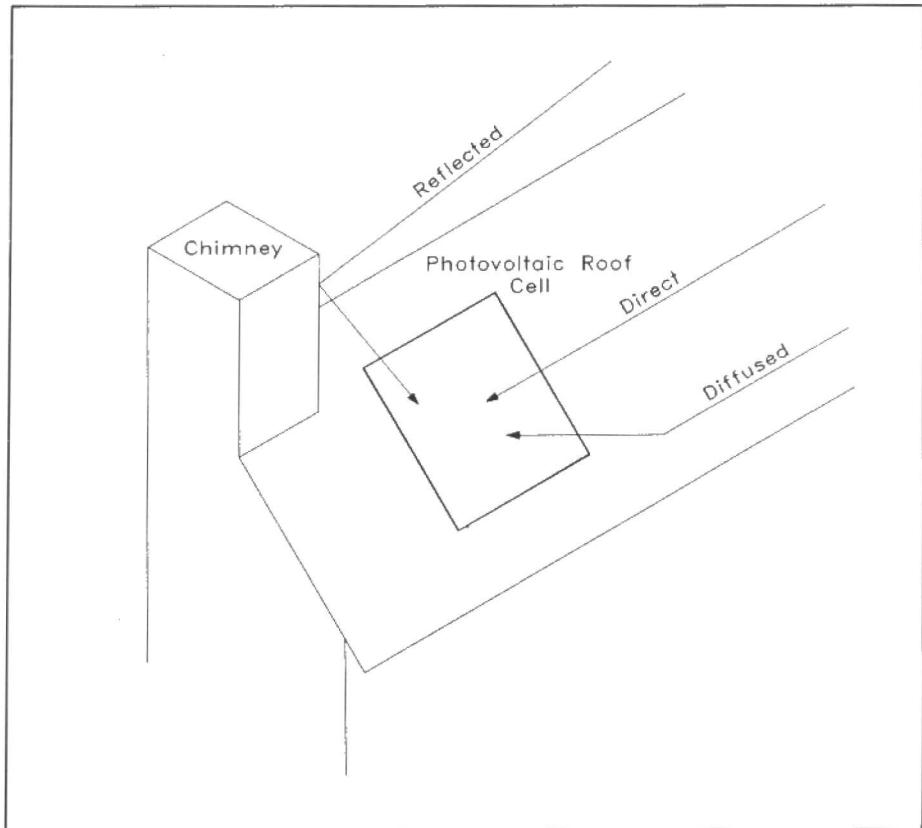


Figure 3. How solar radiation reaches a surface.

natural progression providing a more lightweight and reliable energy source.

In the United Kingdom, photovoltaic products already influencing our lives include radio repeaters, remote weather measuring systems, radio receivers, security systems and water purification systems. Diminishing costs mean that solar generated electricity is already economical for a wide range of applications, particularly in remote locations where other power options are impractical or prohibitively expensive. Provision for a continued supply during the periods of darkness is an important feature of any photovoltaic generation scheme. Moments of maximum demand do not necessarily correlate with periods of maximum solar gain. Supporting research projects continue to perfect battery technology, so that systems may incorporate efficient reservoir mechanisms.

The Future

Whilst a significant amount of information exists which explores every conceivable aspect of CIS, much remains to be explained. Further understanding is necessary before routine production could ever occur. Fortunately it appears likely that data will continue to be accumulated; several research groups are working both in the United Kingdom and abroad. Some academic establishments involved include the University of Salford and Newcastle Polytechnic, and further groups exist promoting and providing support to the photovoltaic cause. Of particular note is the 'Centre for Alternative Technology', based in Powys, an independent charity seeking to demonstrate the potential of renewable energy sources. Interest in establishing photovoltaic industries around the globe

rests mainly in the developing world. The main supporter is the USA with Japan, France and Germany following suit.

Work continues with CIS, exploring the relationship of material properties and device performance. Theoretical modelling and further experimentation seek to stretch the physical limitations of the material. Fabrication techniques remain the subject of investigation since commercially workable production line techniques must be established.

As the sun is a secure, inexhaustible and clean form of energy available to everyone on Earth, it is only sensible to put more effort into the investigation and development of CIS photovoltaic technology. The only way forward is to pursue renewable energy sources, a fact which even the government of old had to admit. A white paper published in September 1990 suggested that 1% of the United Kingdom's energy supply would be provided by renewable sources by the year 2000 - by contrast, Friends of the Earth put the figure at 20% by the 2025. In short, photovoltaic cells offer a safe and secure energy source, one where there is no potential for disaster or harmful environmental emissions.

Sources

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Thin-Film Photovoltaics: Status and Applications to Space Power, G. A. Landis and A. F. Hepp - Proceedings of the European Space Power Conference held in Florence, Italy, 2-6 September 1991.

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Low-Cost Photovoltaic Module Manufacture for Developing Countries (Encapsulation Techniques), G. Watson - Dulas Engineering Ltd., Centre for Alternative Technology.

HM Government's White Paper on Environment: This Common Inheritance - Britain's Environmental Strategy, HMSO, London, September 1990.



RADIO GALORE!

In these modern times we take the wonder of radio for granted. Yet we must not forget that many of the major contributions were originally made by back-room inventors and experimenters. In the first part of 'The History of Amateur Radio', Ian Poole (G3YWX) looks back to the early pre-valve days when enthusiasts had to make their own components. In 'The Inside Story', by the same author, you can find out how a superhet radio works.

TEMPERATURE-CONTROLLED SOLDERING IRON STATION

This design gives you complete control over the heating element of a 50W 24V iron. Safe to use, this extremely versatile unit will enable tip temperatures from 70°C to 450°C to be obtained. Apart from being ideal

for a myriad of electronics-related applications, the value-for-money Soldering Iron Station can be used in many other crafts and hobbies where a controllable heat source is required.

SATELLITE TV

'Give us more satellite TV', we heard you cry! Well, with demands like that, how could we fail to come up with the goods? The first part of the series, co-written by Martin Pipe and Chris Yates, looks back to Telstar before delving inside a satellite receiver to see what makes it tick.

DOMESTIC & BUSINESS SECURITY SYSTEM

It makes depressing (and all-too familiar) reading, but we live in an age when the risk of your home (or business) being burgled is steadily

increasing. The Maplin Security System will provide a high level of protection - at a fraction of the cost of comparable 'big name' systems. In an in-depth article, we will show you how to install this advanced system, which is based around the micro-computer-controlled alarm panel.

INTELLIGENT MOTHERBOARD

This interesting project allows any computer equipped with a RS232 port to record and process analogue data and/or control other apparatus. The heart of the system is the Intelligent Motherboard, which contains a dedicated microcontroller so that the host computer is not significantly 'burdened'. Its expansion board accommodates up to four input/output boards, which will be described in future issues. These include A/D converters and relay output cards.

In next month's super issue of 'Electronics - the Maplin Magazine', there are some really great projects and features for you to get your teeth into! To whet your appetite, here's a taste of some of the goodies on offer:

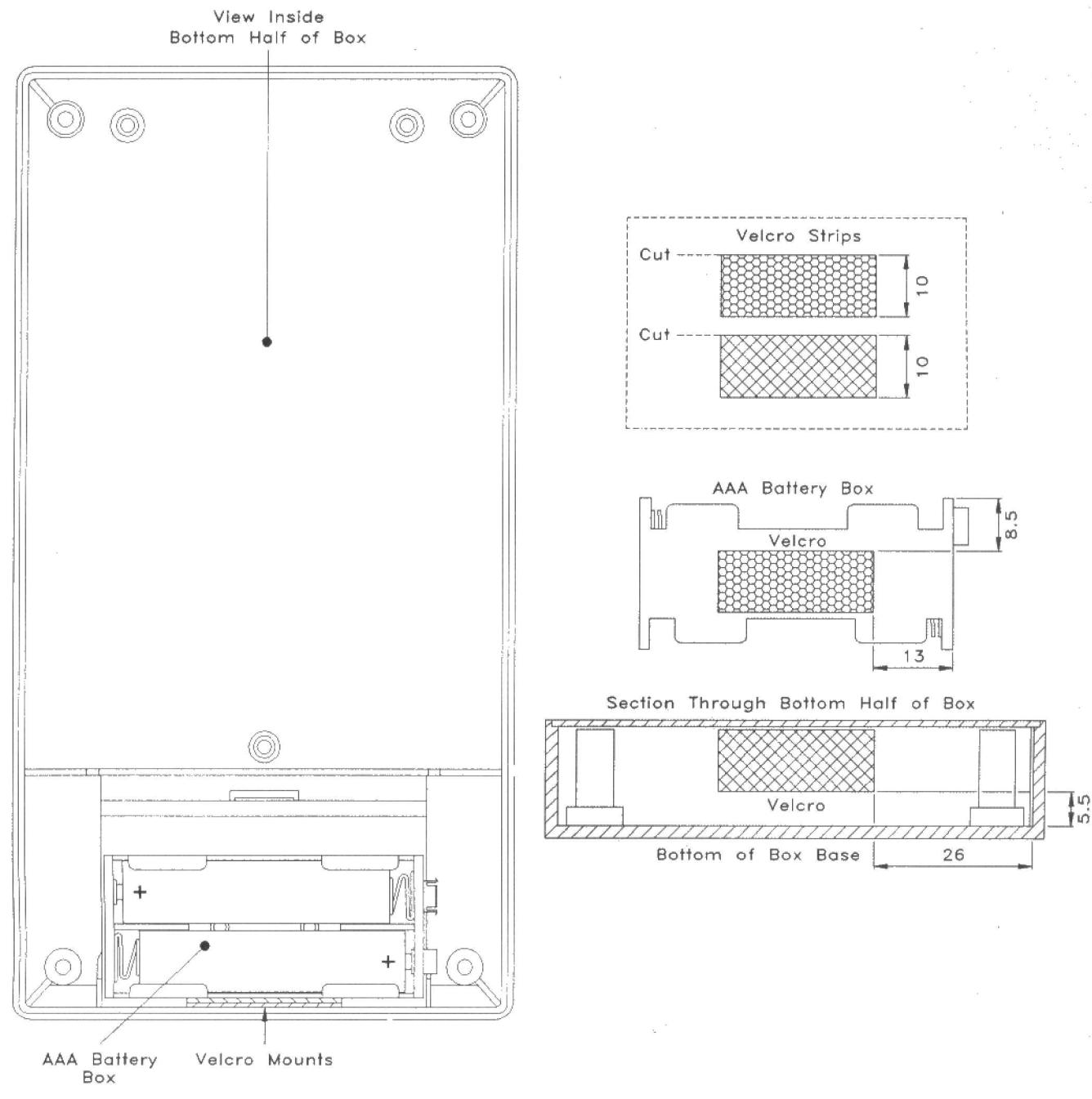


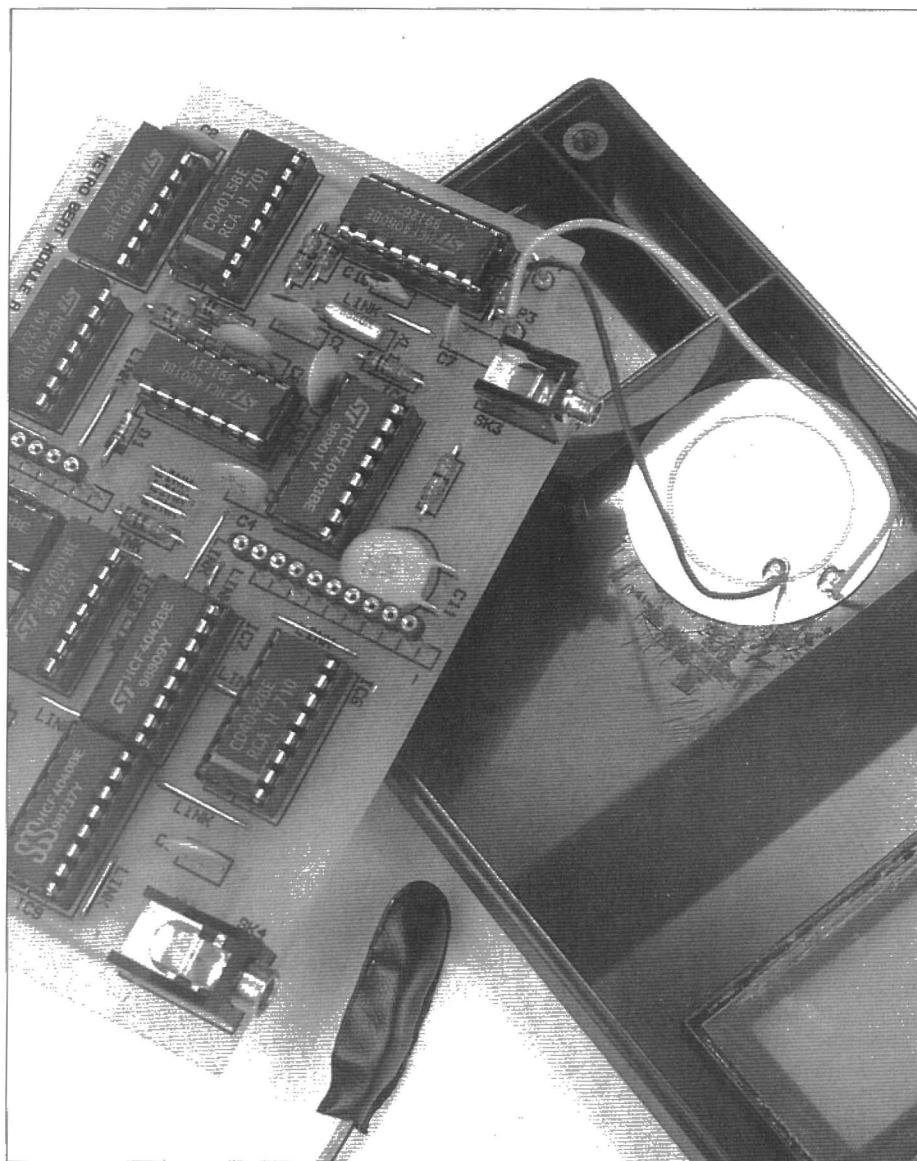
Figure 7. Fitting the Velcro in the battery compartment.

4. Check output IC12 pin 4 – should give a pulse of approximately 50 milliseconds duration after tapping the transducer.
5. Plug switch into 2.5mm jack input SK3 – operating a foot switch leaves the hands free for manipulating the circuit and test gear!
6. Check output IC12 pin 4 – outputs a pulse when the switch is operated.
7. Check for a negative pulse (about 2ms wide) at IC3 pin 11 and IC5 pin 3 when switch is operated.
8. Check that IC9 pin 12 goes low for a period of 2 seconds after momentarily hitting the switch. Clocks should be gated to IC9 pin 10 for this period.
9. Check IC6 and IC7 control inputs: positive pulse on pin 5; positive level on pin 6.
10. Check IC4 pin 3 is normally low but set high after 2 seconds if the switch is held down. It should be set low and stay low on hitting the switch momentarily. Note: this test cannot be done if only using the transducer input – in which case, IC4 pin 3 should be permanently low.
11. Check negative output pulse from IC4 pin 14. This should occur repeatedly at the interval set by two successive switch actions. (Tap the switch twice within 2 seconds.)
12. Check the positive pulse (resetting) IC11 pin 22.
13. Check the negative pulse from IC11 pin 6 – duration approximately 31 milliseconds.
14. Check the positive output pulse from jack socket SK4. This should cause an externally connected LED to flash.

Module B Diagnostics

This module entirely depends on Module A for its operation, which should be in a fully working state before proceeding.

1. After plugging the modules together, check +V and -V on each IC.
2. Check clock output IC18 pin 3; this



The complete Metrobeat PCBs prior to fitting into the case.

should be running at between 400 and 600kHz – actual frequency is not critical.

- Check that output IC21 pin 12 goes low and IC19 pin 7 goes high for a period after hitting the switch. This will gate clocks to IC20 pin 1 for the calculation period of 7680 clocks, i.e. around 15 milliseconds depending on clock frequency.
- Check output IC20 pin 14 – negative pulses should occur after hitting the switch. These will run during the calculation period as the counter is

repeatedly reduced to zero.

- Check that the pulses from IC20 pin 14 appear as positive pulses at the input to display counter IC15 pin 9.
- Check the operation of IC17 pin 13; output should be set low for a period of 2 seconds after hitting the switch and then return high at the next beat time. If the switch is kept depressed, pin 13 should return to a high level at the end of the 2 seconds time-out (being set by input on pin 8) since under these circumstances the action of the strobe on pin 11 will be inhibited.

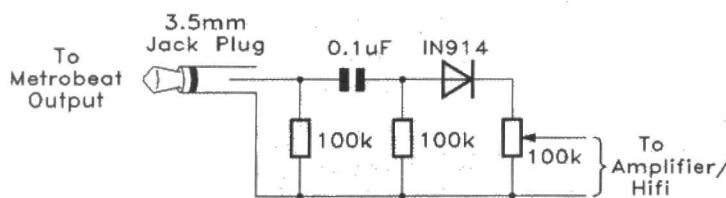


Figure 8. Recommended adapter circuit for producing audible clicks via an external sound system.

- Check the operation of IC22 pin 3. This pin should go high for 2 seconds during which time it will pulse low (negative pulse duration about 31 milliseconds) at the beat rate. At the next beat time after the 2 seconds has expired, the output should go low and subsequently pulse high (positive pulse duration about 31ms as before). The output is forced low by holding the switch depressed.
- Check control inputs to IC15; reset on pin 5 (positive pulse about 2ms wide) and latch enable on pin 6 as output from IC22 pin 3 above.
- Check the operation of leading zero suppression for most significant digit (DY1 display). Output IC17 pin 1 will be reset to low at the start of the calculation period and will be set high only if a carry from IC13 pin 10 occurs. This ensures that the most significant display is switched off for display outputs up to 99.

Case Assembly

When everything appears to be working correctly, the time has come to fit the Metrobeat into its case.

Lower Half

In the lower half of the box, cut a suitable hole for the slide switch at the left-hand side (display at top uppermost) and two holes for the jack sockets on the right – see Figure 5 for drilling details.

Locate the modules in the lower half of the case and locate the battery holder with batteries in the appropriate compartment.

Upper Half

Cut the red plastic display filter to fit the cut-out in the upper half of the case (approx. 28 x 58mm) and glue to the inside of the box using the sachet of adhesive supplied with the kit. See Figure 6 for details. Figure 6 also shows where the transducer has to be glued to the inside of the box in the middle of the upper half between the battery box and the display. Roughen the box surface before applying epoxy resin glue. Lastly, use Velcro to support the battery box, as shown in Figure 7.

Finished or Just Starting?

When the glue is set and the two halves are screwed together, you should have a most useful new device. There's every chance that it will help you pin-point some of your musical problems and could provide a new start in sorting out some of these tricky rhythms.

For driving an external amplifier or the family Hi-Fi, see the suggested circuit in Figure 8. This is arranged to eliminate the double click that would occur if the output were connected directly. My Metrobeat has a permanent place clipped to the music stand, ready to come into instant play when the need occurs.

METROBEAT PARTS LIST

RESISTORS: All 0.6W 1% Metal Film (Unless specified)

R1,10,11	100k	3	(M100K)
R2	1M	1	(M1M)
R3	2k2	1	(M2K2)
R4	10M	1	(M10M)
R5	22k	1	(M22K)
R6,7,8,12	10k	4	(M10K)
R9	220Ω	1	(M220R)
R13-33	470Ω Micro Res	21	(U470R)

CAPACITORS

C1	47μF 16V Minelect	1	(YY37S)
C2-6,13-17	47nF 16V Minidisc	10	(YR74R)
C7	10nF 50V Disc	1	(BX00A)
C8	100nF 16V Minidisc	1	(YR75S)
C9	120pF Ceramic	1	(WX57M)
C10	39pF Ceramic	1	(WX51F)
C11	220pF Ceramic	1	(WX60Q)
C12	220pF 1% Polysty	1	(BX49D)

SEMICONDUCTORS

IC1	4060BE	1	(QW40T)
IC2	4015BE	1	(QW16S)
IC3,5	4011BE	2	(QX05F)
IC4,20	40103BE	2	(QW61R)
IC6,7	4042BE	2	(QX19V)
IC8,17	4013BE	2	(QX07H)
IC9,11,21	4040BE	3	(QW27E)
IC10,12	4001UBE	2	(QL03D)
IC13,14,15	40110BE	3	(QW68Y)
IC16	75491	1	(UF53H)
IC18	4093BE	1	(QW53H)
IC19	4516BE	1	(QW87U)
IC22	4077BE	1	(QW47B)
TR1	BC328	1	(QB67X)
D1	1N914	1	(QL71N)

MISCELLANEOUS

XL1	Crystal 32.768kHz	1	(UJ02C)
SK1,2	20-way Socket Strip	1	(KP51F)

SK3	PCB 2.5mm Jack Skt	1	(FK01B)
SK4	PCB 3.5mm Jack Skt	1	(FK02C)
PL1,2	32-way Through Header	1	(JR74R)
	1/2in. Display Type 4	3	(FR41U)
	Calc-Style Box	1	(YK24B)
	4AAA Batt Box	1	(JG79L)
	PP3 Battery Clip	1	(HF28F)
	Piezo Transducer 35/2.8	1	(YU85G)
	R/A SPDT Slide Switch	1	(FV01B)
	DIL Socket 14-pin	9	(BL18U)
	DIL Socket 16-pin	13	(BL19V)
	PCB A	1	(GH13P)
	PCB B	1	(GH14Q)
	Filter Red	1	(FR34M)
	Double Bubble Sachet	1	(FL45Y)
	Pin 2145	1 Pkt	(FL24B)
	1in. Velcro	1 Pkt	(FE45Y)
	Instruction Leaflet	1	(XT83E)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

AAA Batteries	4	(FK63T)
Plug Plastic 3.5mm	1	(HF80B)
DC Piezo Buzzer	1	(KU56L)

The Maplin 'Get-You-Working' Service is available for this project. See Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LP95D (Metro Beat Kit) Price £34.95.

Please Note: where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately.

(20-way Socket Strip) **Order As KP51F Price £1.36.**

(Metro Beat PCB A) **Order As GH13P Price £3.45.**

(Metro Beat PCB B) **Order As GH14Q Price £6.45.**

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HOW? When you buy a Maplin Kit and if you run into difficulties constructing it, we are here to help you.

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Help is at hand!

For Technical Queries*:

Write to: 'Customer Technical Services', Maplin Electronics, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

We will do our utmost to speedily answer your technical enquiry; or Fax: (0702) 553935; or Phone: (0702) 556001, 2 pm to 4 pm, Monday to Friday, except public holidays.

And if you get completely stuck with your project, get our back-up and we'll get you back up and running!

The 'Get-You-Working' Service:

We will undertake to get working any of the Maplin Kits** published in 'Electronics - The Maplin Magazine'. Please return the completed kit to us at the following address: 'Returns Department', Maplin Electronics, P.O. Box 3,

have made, we will charge you for our time plus parts according to the table below.

Kit Retail Price	Standard Servicing Cost
Up to £24.99	£17
£25-£39.99	£24
£40-£59.99	£30
£60-£79.99	£40
£80-£99.99	£50
£100-£149.99	£60
Over £150	£60 min.

Since most companies charge £30 per hour for maintenance engineers, we consider our standard charges to be extremely low.

If no fault can be found with the project, a charge of £17 will be raised to cover the cost of setting up any equipment needed and the subsequent testing.

We will 'Get-You-Working' as fast as possible, but please allow up to four weeks. We will acknowledge receipt of your returned kit by return of post.

What magazine offers you this kind of service? 'Electronics - The Maplin Magazine' of course!

* We can only answer technical queries related to Maplin projects and products.

** The 'Get-You-Working' Service is available for all Maplin Kits and Maplin Projects with the exception of: 'Data Files'; projects not built on our ready etched PCBs; projects built with the majority of components not supplied by Maplin; Circuit Maker Ideas; Mini Circuits or other similar 'building block' and 'application' type circuits.



PC SOUND GENERATOR

PARTS LIST

RESISTORS: All 0.6W 1% Metal Film (Unless Specified)		
R1	10k	1 (M10K)
R2-5	1k	4 (M1K)
R6,7	47k	2 (M47K)
R8,9	407	2 (M4R7)
R10	1Ω	1 (M1R)
R11,13	2k2	2 (M2K2)
R12	220Ω	1 (M220R)
R14,15	820k	2 (M820K)
RN1	SIL Resistor 10k	1 (RA30H)
RV1,2	Vrt Encr Preset 47k	2 (UH18U)

CAPACITORS

C1,2	10nF Ceramic	2 (WX77J)
C5,6	1nF Ceramic	2 (WX68Y)
C7	PC Elect 10μF 50V	1 (FF04E)
C8,9	PC Elect 100μF 25V	2 (FF11M)
C10,11	PC Elect 470μF 16V	2 (FF15R)
C3,4,12-17	Minidisc 100nF 16V	8 (YR75S)

SEMICONDUCTORS

IC1	74LS688	1 (KP49D)
IC2	74LS02	1 (YF02C)
IC3	74LS244	1 (QQ56L)
IC4	SAA1099	1 (RA81C)
IC5	TDA2822	1 (UJ38R)

MISCELLANEOUS

S1	Slimline 8-way DIL Switch	1 (QY70M)
SK1	PCB 3.5mm Stereo Socket	1 (JM23A)
XT1	Crystal 8MHz	1 (UJ06G)
	DIL Socket 8-pin	1 (BL17T)
	DIL Socket 14-pin	1 (BL18U)
	DIL Socket 18-pin	1 (HQ76H)
	DIL Socket 20-pin	2 (HQ77J)
	PCB	1 (GH19V)
	Instruction Leaflet	1 (XT36T)
	Constructors' Guide	1 (XH79L)

OPTIONAL (Not in Kit)

Lo-Z Mic Preamp Case	1 (FD20W)
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The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or Current Maplin Catalogue for details.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LT10L (PC Snd Generator) Price £29.95.

The following new items (which are included in the kit) are also available separately.

**(PC Snd Generator PCB) Order As GH19V Price £11.95.
(74LS688) Order As KP49D Price £1.86.**

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AMSTRAD PC3286 16MHz, 40MBYTE Hard Disk, VGA Monitor, 1MBYTE RAM 3½in. 720/14MBYTE Disk Drive and with Lotus 1-2-3 for £600 o.n.o. Tel: (0273) 689985.

6264 64K CMOS STATIC RAMS all in component tubes, £1.00 each including P&P. John Symonds, Lower Bungalow, Stoke Water Farm, Bearminster, Dorset, DT8 3JL.

FOUR 256K SIMMS, £6 each. Also for sale, Spectrum +3 with loads of disks, joystick & tape recorder. £85 o.n.o. Tel: Alexis, (01752) 847799.

TO ALL 6502 PROGRAMMERS. Write fast, efficient and compact M/C programs easily using my Assembly Generating Compiler. Its own expandable language implements loop structures, conditional tests, string handling, I/O, integer math etc. in 65XX machine code. Original package runs on C64; source listings can be made available for conversion to another machine. IBM PC version also available. S.A.E. for more details to: Level 3, Aurora, Church Road, Laundon, Essex, SS15 8SL.

PSION ORGANISER TRAVEL PACK.

Includes: Language Translation, Weight and Measurement Conversion. Complete with Manual and Box, all as new. Retails for £40, will accept £25. Tel: (091) 528 1333 after 4pm.

ATARI 520 STFM. No internal floppy or mouse £110. Also 800MB Optical WORM Drive 5½in. Removable discs, ESDI interface. £230. Tel: (0254) 750003.

SUN 2 WORKSTATION 4MB Ethernet SCSI (no disk) mono monitor, offers! Tel: (0252) 878207.

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VARIOUS

AMSTRAD SRD400 SATELLITE RX. 48 Channels, remote control, black mesh dish, 1.2dLNB, brand new condition - 3 months old. Boxed. Bargain at £165 o.n.o. Tel: (0772) 39895.

BRAND NEW dual-tracking 30V 6A DC Power Supply purchased from Maplin for £299.95. Will sell for £165, saving of £134.95. Also Philips CM50 CD ROM drive, originally purchased in Sept. 1991 for £399.99. Boxed and in first-class condition. Will sell for £185, a saving of £214.99. Tel: (0492) 580854 (Conwy).

CLASSIFIED

Placing an advertisement in this section of 'Electronics' is your chance to tell the readers of Britain's Best Selling Electronics Magazine what you want to buy or sell, or tell them about your club's activities - Absolutely Free of Charge! We will publish as many advertisements as we have space for. To give a fair share of the limited space, we will print 30 words free, and thereafter the charge is 10p per word.

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GIANT CLEAROUT! Long list of unused components including ICs, Capacitors, Resistors, some in large quantities. All at bargain prices. Send S.A.E. for list. M. J. Dean, Blerheim, Walton Lane, Bosham, Chichester, West Sussex, PO18 8QF.

OSCILLOSCOPE Scopex 4D10A DC to 10MHz solid-state, dual-trace, £135. Heathkit V-7AU Multimeter £23. Eagle S-Band stereo graphic equaliser £25. Ultrasonic remote control mains switch £15. Tel: (0502) 566026. **100m NYLON-REINFORCED 4-core cable** £15. Blue LEDs £6 each. For list of over 76 LED types. Tel: (0533) 712422, or S.A.E. to R. Lex, 39 New Street, Oadby, Leics, LE2 4LJ.

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Exchange for stereo 8mm camcorder or decent portable stereo VCR. Cash adjustment where necessary. Demo given in Southend area. Tel: Martin, (0702) 603557 (evenings). **ELECTRICAL COMPONENTS**, need to go quickly. Also hard- and software for Amstrad CPC computers, must go soon. Send S.A.E. to: Alistair Brown, 1 Park Gate Crescent, Guiseley, Leeds, LS20 8AT

OSCILLOSCOPES for sale: Tektronix 564B (Storage, Dual, 10MHz) and Tektronix 2215 (Dual, 60MHz). Offers around £100 and £300 respectively. Tel: (0638) 663326 for details.

WANTED

TWEETER for Goodmans RB 18 speakers. Must have red dome. Will consider faulty pair of speakers. Tel: Mark, (0742) 402774 (Sheffield).

1.5m OR 1.8m PRIME-FOCUS SATELLITE DISH with polar mount and stand. Must be cheap and in South-East Essex area. Any condition as long as it's still parabolic! Also front control flap and remote control unit for PANASONIC TC2232 colour TV. Contact Martin on (0702) 554155 ext. 282 (office hours).

ANY INFO. and help on Radio Shack TRS80; diagrams, manuals, discs, etc. Will refund costs. D Kurtz, 17 Acresfield, Adlington, PR7 4JZ.

AUTO-VIDEOCASSETTE CHANGER! Will anyone help an old Betamax Fanatic? I'm looking for the Sony AG-7UB changer for use with the Betamax C5/C7, preferably in working order and for a fair price. Tel: Mr. Raymond Lockton, (0392) 538338 (Exeter).

CIRCUIT OR PCB track diagram for an AMTRON UK677 Power Supply. Will reimburse any cost incurred. Write to: R. Norville, 131 Stanshawe Crescent, Yate, Bristol, BS17 4EG.

I HAVE A SONY PS-LX5 turntable but no instructions or wiring diagrams. Can anyone help? Will buy, beg or borrow! All reasonable costs met. Tel: David, (0978) 758313.

EPROM PROGRAMMER AND ERASER.

Atari ST with software for sale, or may swap for above. Tel: Stephen Done, (0628) 485946.

CIRCUIT DIAGRAM or information on FM/MW radio with pre-set stations for A-Level Electronics project. Write to: Paul Norris, 58 Overdale, Ashtead, Surrey, KT21 1PT. **MICROPHONE MIXER** and 3/4 channel stereo audio mixer/fader. S. Pirie, 15 Strak Road, Skene, Aberdeenshire, AB32 6TN. Tel: (0224) 743120.

MUSICAL

ELECTRONIC ORGAN components clearout - keyboards, stop tabs, etc. S.A.E. for list to: Fred Wright, 23 Merrion Close, Moorside, Sunderland, Tyne & Wear, SR3 2OP.

ELECTRONIC ORGAN. Elka Minuet 99 with tutorial lessons, 2 keyboards, bass pedals, rhythm accompaniment, roll top. Walnut veneered. Offers! Tel: (081) 500 6526.

CLUB CORNER

ELECTRONIC ORGAN CONSTRUCTORS SOCIETY 2.30pm, May 16, St Pancras Church Hall, Lancing St, near Euston station, all welcome. Regional meetings. Tel: (081) 902 3390. 87 Oakington Manor Drive, Wembley, Middlesex.

TESUG (The European Satellite User Group) for all satellite TV enthusiasts! Totally independent, TESUG provides the most up-to-date news available (through its monthly 'Footprint' newsletter, and a teletext service on the pan-European 'Super Channel'). It also provides a wide variety of help and information for its members. For further information, contact: Eric W. Wiltshire, TESUG, Rio House, Stafford Close, Ashford, Kent, TN23 2TT, England.

THE BRITISH AMATEUR ELECTRONICS CLUB (founded in 1966), for all interested in electronics. Four newsletters a year, help for members and more! UK subscription £8 a year (Junior members £4, overseas members £13.50). For further details send S.A.E. to: The Secretary, Mr. J. S. Hind, 7 Carlyle Road, West Bridgford, Nottingham NG2 7NS.

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MODEL RAILWAY ENTHUSIAST? How about joining 'MERG', the Model Electronic Railway Group. For more details contact Mr. Eric Turner, Treasurer MERG, 38 North Drive, Orpington, Kent, BR6 9PQ.

ICs do the Splits!

Dear Sir,
I have constructed a Velleman kit – the Morse Decoder, reviewed by Gavin Cheeseman in the May issue of Electronics – The Maplin Magazine'. Let me congratulate you on obtaining the franchise to market Velleman Kits. This one is superb. The PCB is excellent with insulated connections between the pads on the foil side and a very good legend on the component side.

There is one complaint I have about most of the kits obtained from Maplin and other component retailers – IC pins are not bent to fit the sockets provided. One has to bend them oneself which is not always easy, particularly with CMOS ICs. I grip the IC with an insertion tool (FR25C) held in my hand (which is earthed by a wrist strap), and bend the IC pins on an earthed aluminium plate screwed to my workbench. This is fine for 14 to 20-pin ICs but the insertion tool will not fit any larger than this. In the case of my Morse Decoder kit I had to bend the 40-pin IC as best I could and hope that it was not CMOS!

R. G. Ticehurst, N. Yorks

The fact that IC legs are splayed slightly, is down to the manufacturer not the supplier, I believe that automatic insertion equipment actually requires ICs to be supplied in this form (IC data sheets often give precise limits within which the leg-splay will fall!)

I am sure that you, and others, will be pleased to know that Maplin sell an inexpensive tool whose sole purpose in life is to bend DIL IC pins so that they will fit into PCBs and sockets. Featured in the 'Semiconductors' section of the new 1993 Catalogue, this tool (Order Code KU42V) will cope with 40-pin ICs as well as the smaller ones. In common with your ingenious method, static protection is incorporated (the tool can be earthed) but, you will find, it is a lot quicker – and easier too!

Pro Amp Explained

Dear Sir,
Excellent! At last we now know how to put together a 150W Pro Amp, but there are no explanations of the following design aspects:
1. Why do you insulate the XLR connection. Is this always done, if not, why?
2. You use the SSM2016, why not use the SMM2015, or any other preamp?
3. The SMM2015 is AC-coupled already, so why build a board with two capacitors to fit the SSM2016?
4. I remember someone writing in one of your magazines, saying that these capacitors should be linked out and you agreed. Does this rule only apply to the SSM2016? (very confusing)
5. Why have you used a 4k7 pot – the input impedance is 47k; how does this relate to a 4k7 pot? If you used the 50W amp (CW35Q), which has an input impedance of 15kΩ, would a 4k7 pot be used – or is there a formula for working out the relationship?
6. How would you add, say, another 3 MIC inputs?
7. How would you add a feedback filter? Perhaps you could produce a circuit for one of these.
M. G. Holt, Rochdale

1. 3-pole XLR connectors have four terminals, three of which are used

6. To add more inputs, it would be better to have a separate mixer feeding the amplifier.
7. As 6, use a separate unit.

Horses for Cases

Dear Sir,
Why are 19in. rack mounting instrument cases so prohibitively expensive? They do not seem (in the catalogue at least) to be any better quality than the other cases offered. On a number of occasions I have had a project that would probably be best fitted into one of these, but I have never been able to afford one. More recently I have found the need for a decent PSU, and have decided that I will not cut corners, building it into one of the above cases. I intend to use the low-cost PSU featured in the November 1991 Issue. Will it fit into a 19in. case that is 2U high (e.g., XM68Y)? Is it possible to stack rack mounting cases, without actually having a rack? When I come to design the front panel will I be able to mount the actual PCB elsewhere in the case, i.e. away from the front panel?

David Forbes (aged 16), Clwyd.

19in. rack-mounting cases are expensive simply because they are so well-made! This standard, lest we forget, was originally conceived for professional applications, which are normally a lot more demanding than those encountered in a domestic environment. The cases shown in the Maplin Catalogue are made from decent-grade mild steel sections that are screwed together (less expensive cases, good though they are, are simply made from folded aluminium sheets!). Although 19in. rack-mounting cases could be considered as 'overkill' for projects like the 'Low-Cost PSU', it must be considered that the case manufacturers are unaware of what professional users may incorporate into their products; a case may have to withstand the weight of several mains transformers, cooling fans, a large number of densely-populated PCBs and a plethora of front/rear-panel weakening sockets and switches! You could incorporate the Low Cost PSU into a 2U-high 19in. case, but you would need to mount the PCB horizontally on the bottom of the case (don't forget those insulating spacers!), wires being used to connect the PCBs to the front-panel connected controls. The transformer recommended for the kit is WB22Y, which is 75mm high. Bearing in mind that the 2U case gives a vertical clearance of 78mm, you'd be cutting it rather fine! Why not make things easier (and cheaper) for yourself by fitting the project in a less expensive box that will allow mounting of the PCB on the front panel, while providing enough space for the transformer? XJ28F, the sturdy steel case recommended in the original article, is an ideal choice. The whole point of 19in. rack-mounting cases is that they mount in a rack. When an engineer wishes to service a piece of equipment in a professional installation, the use of a rack means that he/she can get to it easily and safely – whether it is at the top or bottom. Another point; imagine ten pieces of heavy equipment stacked atop each other without ventilation space – and the weight being applied to the bottom cabinet!

STAR LETTER

This month Mr M. R. Perry from Kidderminster receives the Star Letter Award of a £5 Maplin Gift Token for his letter on Bi-Colour LEDs.



Making the Most of those Bi-colour LEDs

Dear Sir,
The specification of the QY83E bi-colour LED, in the 1992 catalogue, states that the forward voltage of the LED is 2V, while the reverse voltage is 5V (max). As the red and green elements of the LED are connected in inverse parallel, the maximum reverse voltage is somewhat irrelevant as the forward drop of each LED protects its counterpart to a maximum reverse voltage of 2V. (Don't forget that current-limiting resistor, though – Ed!) This self-protection has a side advantage in that the LED can be driven directly by low-voltage AC

supply, the prevalent colour depending on the angle of view.

The miniature version (UF96E) could also be used on AC for the same reason, but I have not tried it for the colour effect.

While writing I think it is worth mentioning that 4-core individually screened cable (XR23A) is ideal for RGB/composite sync computer monitor leads, as well as composite video/stereo audio/switching cables for video recorders and so on. Each core of my sample had an impedance of around 65 ohms – close enough (for most practical purposes) to replace 4 separate 75 ohm coaxial cables.

Thanks for the tips!

for the signal connections, the fourth connects to the metal case. Many XLR cables are wired so that the case and signal screen are connected together. If such a cable is plugged into a piece of equipment with a metal case, where the chassis mounted XLR connector is connected directly to the case, a multiple earth path may be created. This situation may cause hum. For this very reason, the IEC publication that deals with such matters, says that XLR cables should not be wired with the case and signal screen connected together. Since there is some confusion, the Pro Amp adopted a 'belt and braces' approach, by insulating the XLR connector from the case.

2. & 3. SSM2015 is primarily a microphone preamp, the SSM2016 is better suited as a general purpose input preamp. Since the signal source could have a DC offset on its output, AC coupling is employed; on the

SSM2016 PCB this is not catered for and had to be added off-board.

- 4. Yes and no, depending on the application! The capacitors should only be linked out if they are definitely not required in the particular application. The capacitors on the SSM2015 board can be linked out if phantom powering of microphones is not going to be used.*
- 5. The passage of an electric current through a resistor generates noise; generally speaking the lower the value of the resistor the less noise it contributes to the circuit. When connecting a signal (voltage) source to a load, it is good practice to ensure that the signal source impedance is at least ten times lower than the input impedance of the load. This will ensure that, voltage wise, most of the signal is transferred to the load. The potentiometer is both load to the preamp and source to the amplifier; 4k7 suits both fine and doesn't generate much noise!*

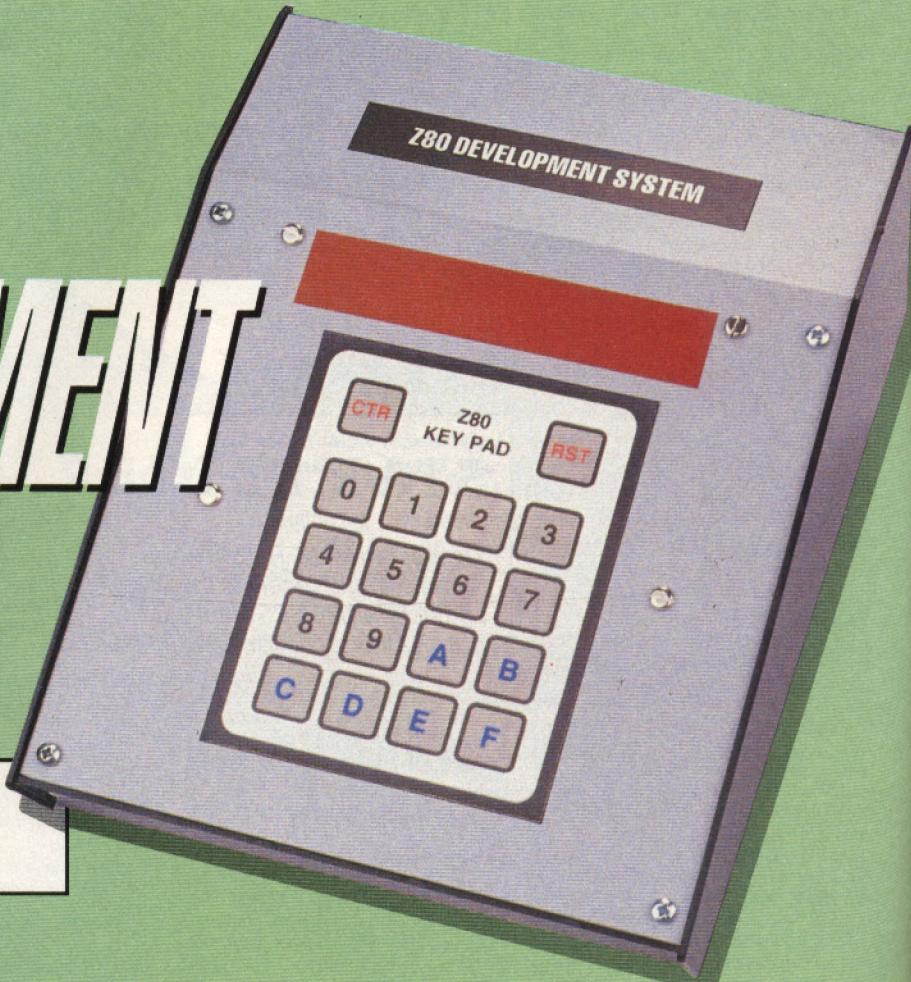
2ND Time Around

THE Z80A DEVELOPMENT SYSTEM

IDEAL FOR
EDUCATION

by the Maplin Development
Team and Graham Dixey
C.Eng., M.I.E.E.E.

Particular projects from the Maplin range have proved themselves to be very popular, but technology and component specifications have a habit of changing, with the result that some of these projects are in danger of becoming obsolete. Even if this were not the case, it may be equally worthwhile improving the project in question in order to increase its versatility and usefulness, and bring it 'up-to-date.' The '2nd Time Around' series is dedicated to reviewing and improving original, popular Maplin projects by republishing them with the necessary updates and improvements, ensuring their continued availability. This time it is the turn of the Z80A CPU and the Z80 Keypad.



The complete Z80A Development System ready for use.
(Please note: the box shown is not included in the kit).

APPLICATIONS

- ★ Software development
- ★ Control applications
- ★ Education

Z80A CPU MODULE

FEATURES

- ★ Accepts up to 8K of on-board memory
- ★ Has facilities for keyboard and displays
- ★ 4 decoded I/O select lines
- ★ Battery back-up available for CMOS RAMS
- ★ Monitor EPROM available

Z80 KEYPAD

FEATURES

- ★ Type in your own Hex Code easily
- ★ Ready to use splashproof membrane keypad
- ★ Large double-digit displays
- ★ Key-press beep
- ★ Simple construction

Overview

The Maplin Z80A Development System is based on an existing kit (the Z80A CPU Card) and a new one (the Z80 Keypad). Astute readers may recall that there was already a keypad available for use with this item, and may wonder why a new one needs to be introduced at all. This is because the keypad switches used on the original version are no longer available, and at the same time it was felt that the design could be improved, providing additional features. The article that follows also looks at how the two units can be integrated to form a complete development system.

Z80A CPU Card – An Introduction

The Z80A microprocessor has been with us for many years and is still proving to be a popular choice for many applications. Practical uses of this CPU require a

module with memory, Input/Output (I/O), clocks and facilities for further expansion.

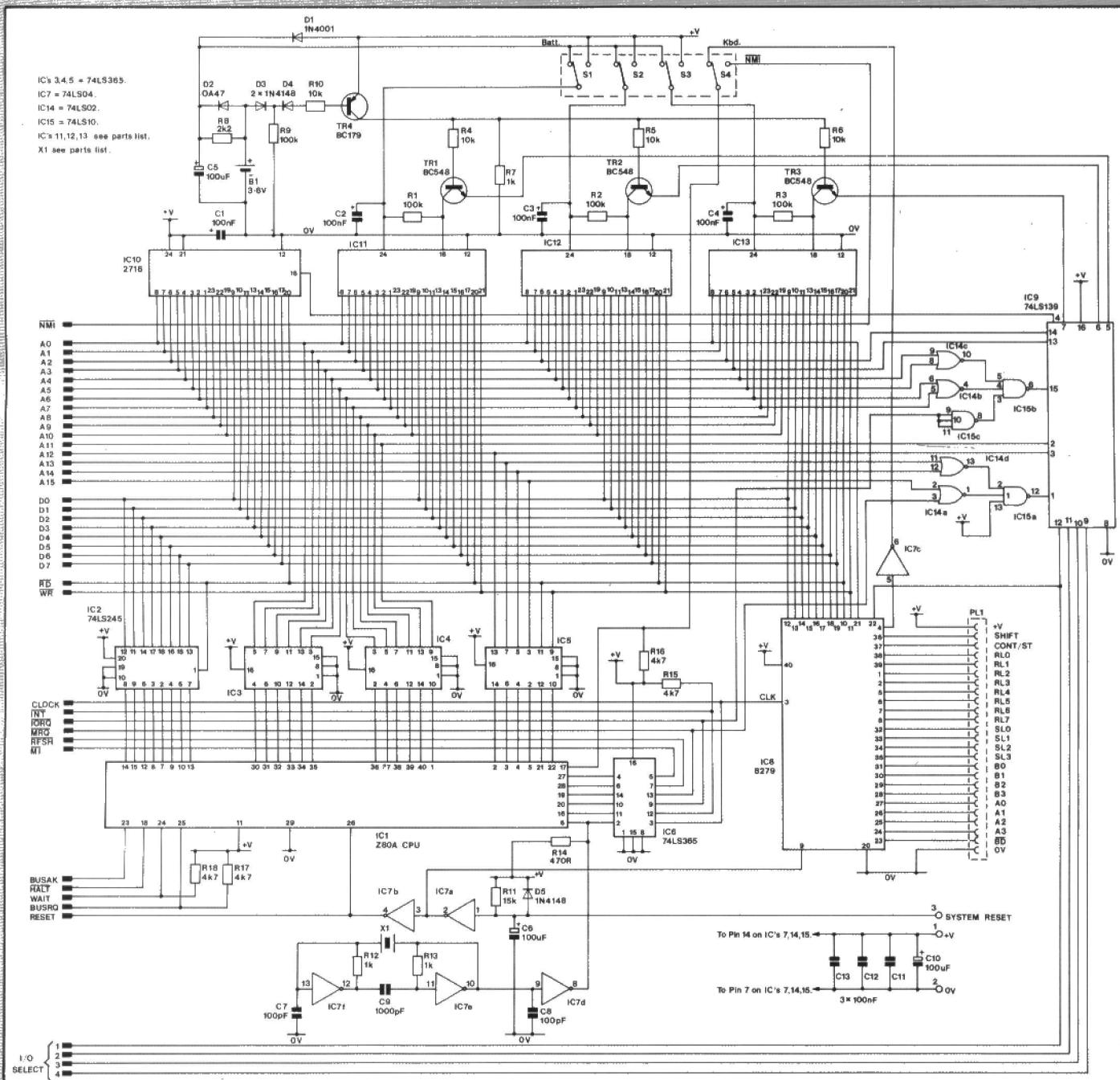
The Z80A CPU Module can accept up to 8K of memory which is decoded in 2K (2048 bytes) blocks. The first block contains the operating system in ROM or EPROM and the second, third and fourth blocks can be either RAM, ROM or EPROM. Static CMOS 2K RAMS may be fitted (totalling 6K) and switched battery back-up is available, for CMOS data retention, if required.

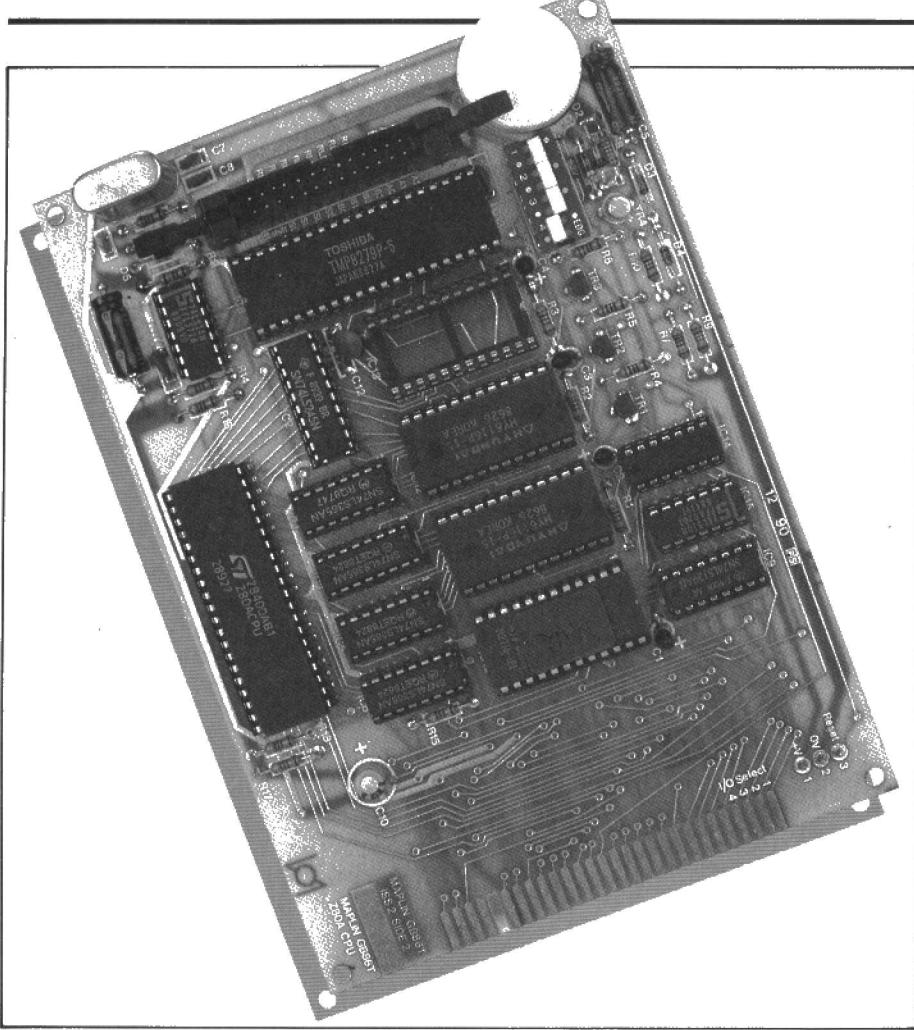
A keyboard/display decoding IC can be fitted, allowing for small keypads (such as the Z80 keypad described later on in this article), large (64-key) type keyboards, or sensors for data input. This IC can also drive seven segment LED displays. Four decoded I/O select lines are available on the module and all data, address and common control lines are buffered before being brought out to an expansion edge connector.

Circuit Description

Figure 1 shows the circuit of the Z80A module. IC1 is the CPU – 'heart' of the system – and is driven by a clock generator, IC7d to f, with frequency set by crystal X1. Resistors R12, R13 and capacitors C7 to C9 are chosen for 2.4576MHz operation and can be varied to suit higher frequency crystals of 3 to 4MHz. Power-up reset components R11, C6 and IC7a&b hold the Z80A in a reset condition for approximately 500ms when power is first applied. Further resets can be performed by taking the SYSTEM RESET input pin, P3, low (0V) at any time after power-up. Data lines D0 to D7 and address lines A0 to A15 are buffered by IC2 to IC5, and are then extended to IC10 (the ROM), IC11 to IC13 (the ROM/RAM), and IC8 (the optional keyboard/display decoder).

Switches S1 to S3 connect B1, the back-up battery, to ICs 11, 12 and 13. If





The assembled Z80A CPU Card fitted with optional monitor EPROM and 8279 keypad/display IC.

back-up power is not required, then S1 to S3 should be set in the '+5V' position. B1 is trickle charged from the +5V rail; here, power is applied at a tiny 2mA (set by R8). Diode D1 supplies both battery and RAM ICs when the power is turned on, whereupon diode D2 becomes reverse-biased. TR4 is turned on during normal operation and its collector provides base current for TR1, TR2 and TR3. These three transistors have their emitters controlled by IC9, which decodes in 2K blocks when addressed by the CPU. With IC9 outputs not selected, all three transistor emitters are held close to their base potential and no current flows. The chip select CE (pin 18 of ICs 11, 12 and 13) are also held high by pull-up resistors R1 to R3; thus none of the RAMs are selected at this time. For the CPU to read or write data at a valid RAM location, the appropriate address must be set up on A0 to A15. For example, address 2048 is valid at IC11; this is found by taking address lines A0 to A10 low, A11 high and A12 to A15 low. During a memory read cycle, MREQ is taken low and IC9 gives a decoded LOW output on pin 5. TR1 emitter voltage drops and collector current flows pulling IC11 pin 18 (CS - chip select) low. The read (RD) line, when low, will enable all data output buffers within IC11, and stored data will be presented on the data bus (D0 to D7). Two-way communication between data bus and CPU is then determined by IC2.

This IC allows data to be transferred from the bus to the Z80A when the READ

line (IC2, Pin 1) is active. Conversely, when READ is inactive all Z80A data is sent out to the bus. This method of buffering, along with IC3 to 6, effectively isolates the CPU from external devices, thus keeping its power requirements low and preventing possible damage from short circuits. Diode D2 becomes forward-biased if the 5V supply is removed. Battery B1 will then supply 3.6V to switches S1 to S3, thus obtaining low-power data retention, providing that IC11 to 13 are not selected - and TR4 turning off at this time ensures this does not happen!

IC9 is a dual decoder - one half of which decodes RAM, while the other half decodes I/O. Four I/O select lines are available, one of which also selects IC8, the keyboard/display interface. S4 routes the NMI (Non Maskable Interrupt) for the CPU from either the edge connector, or the interrupt output (IRQ) of IC8. The output of IC8 pin 4 is active high, while the CPU's input is active low; to save the CPU from a state of semi-permanent interruption, an inverter (IC7c) has been inserted between them!

Construction

Construct the module, following the usual rule of starting with the smallest components first and working up to the largest ones. For your guidance the PCB layout is reproduced in Figure 2. Do not insert the ICs at this stage. Further tips on construction techniques may be found in the

Constructors' Guide (XH79L), which is included in the Kit.

Clean up the board, by cutting off excess wires, and with a PCB cleaner and a stiff paint brush, wash off any flux before inspecting the module. A close inspection of all tracks, joints and components is especially recommended on this board, as very little information can be given as to where faults may lie if the module does not function properly later on.

Initial Testing

A multimeter set to read high ohms ($\times 10k\Omega$ or more) should be used to check for shorts between the address, data and control line connections along the edge connector. Then use the lowest resistance range to check for continuity along these connections. For example, with reference to Figure 1, it can be seen that D0 to D7 is common from IC2, IC8 to IC10 and the connector. Check for shorts between these data lines and also check for continuity from the furthest point (IC8) to the data output pads on the edge connector. Repeat these checks on Address/Control busses from ICs 3 to 6 and the edge connector.

If all is well, power can be applied to the module, but *do not* insert the ICs at this stage. A +5V supply, well smoothed and regulated, is required and should be connected to terminals 1 (+5V) and 2 (0V) at the top corner of the expansion connector. Set each switch (1 to 4 in the switch bank) up towards D1 and D2. This is noted on the legend as '+5V' and 'INP' for the NMI input line. Switch on the supply and with a meter set to a suitable DC volts position, check for +4.7 to +5V across C5. A negative reading could mean reversed meter connections or a reversed supply connection. If the correct voltage is given, leave the supply on and check the battery voltage between 0V and D2 anode, which is the opposite end to the one marked with a band. The voltage reading may be low at this stage (possibly +1 to +3V). Let the battery charge, and watch the voltage rise towards +4V, which will take a little while.

Now check the collector of TR4 to 0V. With power on, the reading will be about +4.8V while the battery voltage is low, and approximately +2V when the battery has become fully charged. This is due to TR4 being biased partly off, when the battery is at full potential. Switch off the power, and TR4 collector voltage should drop to 0V. Now take a reading on IC13 pin 24, re-connect the power and check that with S3 in the '+5V' position, a voltage of +5V is present on this pin. Set S3 to 'BATT' and the reading should drop to +4.3V. Repeat this test on IC12/S2 and IC11/S1.

Leave the switches set in their present positions, and check the collectors of TR1 to 4 in turn - a reading of +3.5V should be found here. Switch off the supply and repeat the tests, noting that the voltage will have dropped to approximately +3V. These voltage readings are much dependent upon the type of equipment used to take the measure-

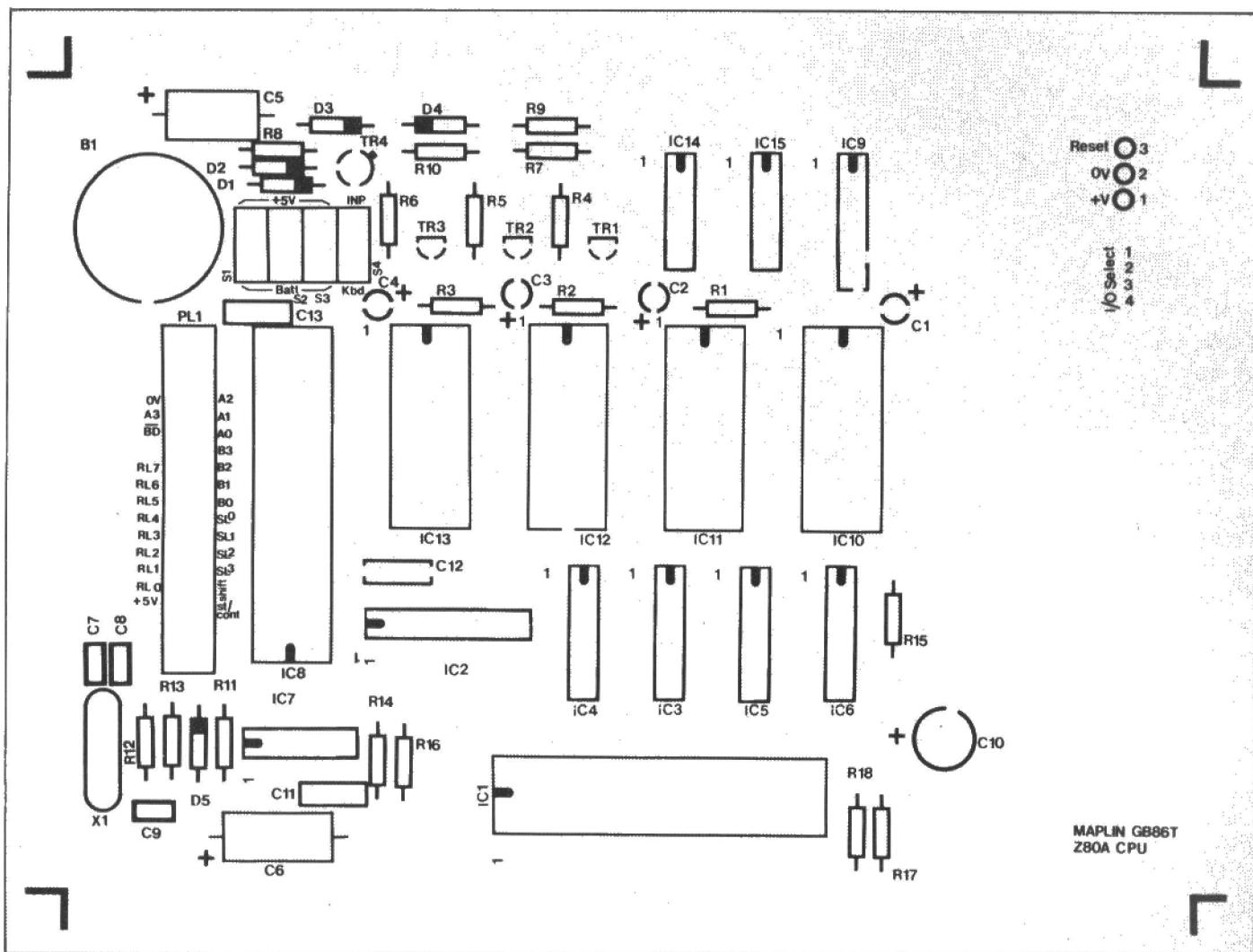


Figure 2. Z80A CPU module PCB layout.

IC	Address	(&H)	IC9 PIN	Function
10	0-2047	0000-0FFF	4	2K ROM only
11	2048-4095	0800-0FFF	5	2K ROM or RAM
12	4096-6143	1000-1FFF	6	2K ROM or RAM
13	6144-8191	1800-1FFF	7	2K ROM or RAM

Table 1.

ments. An oscilloscope with $1M\Omega$ impedance probe and a digital multimeter were used to take measurements for this procedure. Lower impedance equipment such as $20k\Omega/V$ moving coil meters will naturally give lower readings and this must be kept in mind if large differences are apparent.

Memory and I/O Map

Four memory select lines are internally decoded by IC9 as shown in Table 1. Each IC9 output shown decodes a 2K (2048 byte) block starting at 0000. The first block should contain ROM or EPROM and the operating system is resident here (IC10).

The next three ICs can be either ROM or RAM, with switched options available for 2716 type EPROMS or 6116 CMOS RAMs. Further memory decoding above &H1FFF (8191) is not available on board and may be added externally.

Four I/O decoded outputs are available from the expansion connector as

I/O Select	Address	(&H)	IC9 PIN	Function
1	0 to 3	00-03	12	KBD/Display
2	4 to 7	04-07	11	I/O Select
3	8 to 11	08-0B	10	I/O Select
4	12 to 15	0C-0F	9	I/O Select

Table 2.

shown in Table 2. I/O select lines occupying the first sixteen addresses are decoded in blocks of four. This means that each I/O line has four addresses associated with it, and I/O select line 1 is also common to the keyboard/display interface IC. Further decoded I/O lines above &H0F (15) are not available on board and may be added externally in conjunction with IORQ and MI.

Control Lines

All of the Z80A control lines are available, most of which are buffered, including a system CLOCK output, RESET output, SYSTEM RESET input and a switched NMI input. The NMI can be taken from either keyboard/display interface IC8 or directly from the expansion connector.

If the system bus is to be used by external devices during BUSRQ-BUSACK time then problems will be encountered due to IC2. Normally, the Z80A data bus will be high impedance at this time, thus freeing the bus for external device use.

IC2 will be in WRITE mode and this means that its data bus outputs will always be at TTL level, thus the bus will not be free! If required, IC2 could be omitted and links connected between each of the eight input to output pins to allow external bus use.

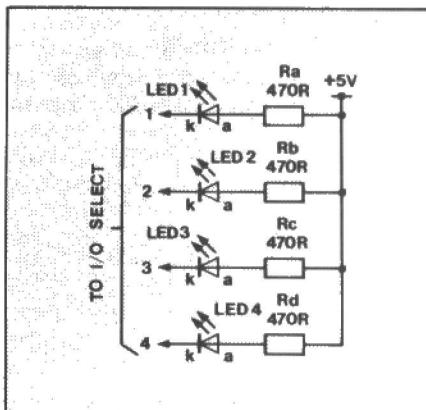
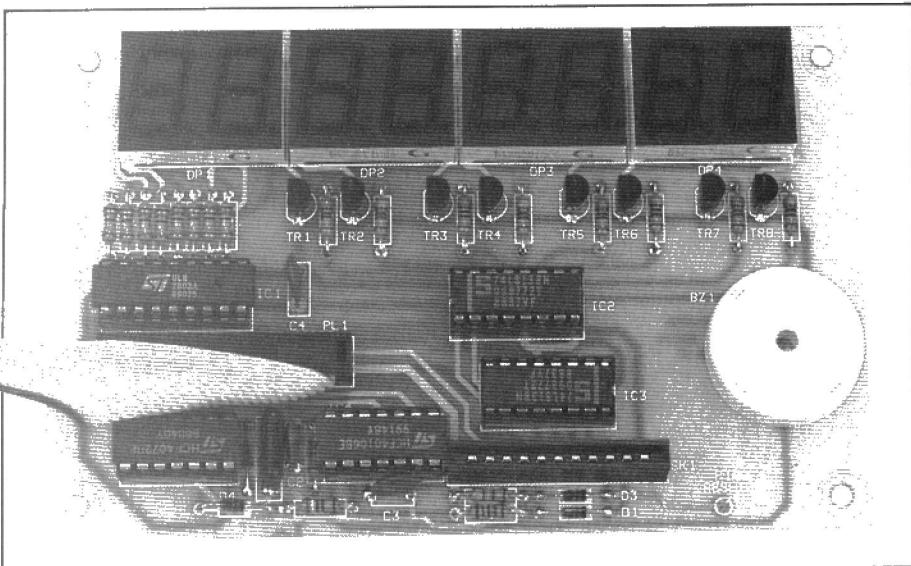


Figure 3.



The assembled keypad display PCB.

Keyboard/Display

The 8279 is a very comprehensive IC capable of scanning keyboards or sensors, and also driving 7 segment LED displays. The interface can scan up to 64 keys – expandable to 128 with suitable decoding – and sensors or strobed keys may be used. Two key lockout and 'N' key rollover can be programmed, and keyboard entries generate an interrupt (NMI) to the Z80A. Either four or eight (programmable) 7 segment displays can be added with blanking facilities, and all connections are made via a 26-pin IDC socket (PL1), as shown in Figure 5.

The 8279 IC is used to drive the display, and operate the keyboard, of the companion Z80 keypad project.

Expansion

This module is intended for use as the central processing section of either a complete microcomputer system, or used purely for experimental/educational purposes, or it can be used on its own as a 'simple' MPU based control system. Note that all the data address and system control lines are available on the expansion connector, shown in Figure 4. Z80A physiology and architecture is not detailed in this article as such a complex subject requires a great deal of careful study. A great many books, some of which are listed for reference, are available to assist in the development of this subject, but for the more initiated, further testing routines follow.

Further Testing

Further testing may be carried out by building and using the Z80 keypad

project. If however, there is a fault on either the Z80A CPU or Z80 keypad, it may not be possible to determine easily which is faulty. In this instance, or if the Z80 keypad is not required, the following instructions will assist testing. However, a Z80A assembler/ROM emulator/EPROM programmer will be required to perform these tests.

Figure 3 shows a simple LED indicator using the four I/O lines. The cathode of each LED is connected directly to the four I/O select lines 1 to 4 and each anode is connected via a current limiting resistor to the +5V supply. With the power off, insert all ICs and either a ready programmed EPROM or connect a suitable ROM emulator.

There is no 'easy' way to test CPU modules, as instruction sequences must be made available to the Z80A. An EPROM/ROM emulator must be programmed with either test routines or your development program, using the memory and I/O information given or taken from Machine Code listings 1 and 2.

Listing 1 is a 6 byte routine which operates one of the LEDs 1 to 4. The particular LED I/O address 00 to 0F is determined by the fourth byte. If IC8 is fitted, set S4 to 'INP'. Listing 2 is a 6K RAM test routine which assumes ICs 11 to 13 are fitted and switched to standby (BATT) mode.

LED 4 indicates IC13 being tested; LED 3 indicates IC12 being tested; LED 2 indicates IC11 being tested. LEDS 2 and 3 together indicate a successful test. LED 1 + (LED 2 to 4) together and flashing indicate a fault in the RAM designated previously.

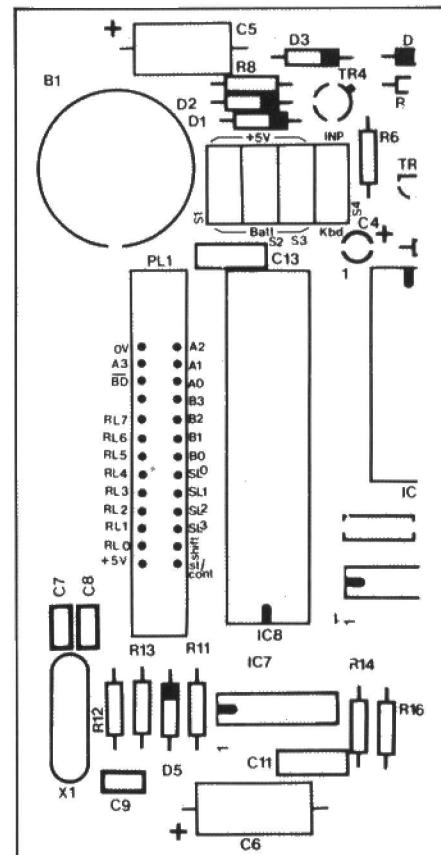


Figure 5. PLL connections.

When using CMOS RAMs a data retention test can be made as follows:

Address (*)	From	To
09	00	01
0A	70	00
13	10	00
14	F5	00

5. Switch supply on again and run routine 2.

This time the test looks for data 01 previously stored before the first power down and checks all 6144 locations. LEDs 4, 3 and 2 step sequentially, then all three turn on together if the test is successful. Otherwise faults are indicated as before.

The four LEDs in Figure 3 serve as a simple indicator and will only work if the I/O decoding section is fault-free. They will not give a meaningful indication if either the routine, bus connections or I/O decoder are faulty.

Data Sheets	Description
Z80A-CTC	Counter-Timer
6116-3	2K CMOS RAM
Z80A-DART	Serial Controller
Z80A-PIO	Parallel Controller
8255A	Peripheral Adaptor
8279	Keyboard/Display Interface
6402	UART
8251	Communication Interface
8250	UART
2716	2K EPROM

Table 3.
Data Sheets available from Maplin.

Ld A,N	3E,FF	: DATA TO OUTPUT
OUT (n),A	D3,00	: n = (00-0F) PORT
JR	18,FA	: REPEAT

Listing 1. I/O Port Test.

Ld DE, NN	11 00 00	RESET COUNTER
Ld C, N	0E 0F	PORT #4 (0F)
Ld HL, NN	21 FF 1F	RAM TOP = 8191
Ld B, N	06 00	INITIALISE DATA (*)
Ld (HL), B	70	WRITE DATA (*)
Ld A, (HL)	7E	READ DATA
CPB	B8	IS RAM O.K?
JRNZ	20 21	NO - GO FAULT RTNE
Ld A, B	78	YES - STORE COUNTER
OUT (c), A	ED 79	OPERATE LED
Ld B, A	47	RESTORE COUNTER
DJNZ	10 F5	REDUCE COUNTER (*)
DEC HL	2B	NEXT ADDRESS
INC DE	13	COUNTER +1
Ld A, N	3E 08	END OF CURRENT RAM?
CP D	BA	(2048 BYTES TESTED)
JRNZ	20 EB	NO - GO INITIALISE DATA
Ld DE, NN	11 00 00	YES - RESET COUNTER
DEC C	0D 0D 0D 0D	SELECT NEXT LED
Ld A, N	3E 07	6K TESTED?
CP H	BC	
JRNZ	20 E0	NO - INITIALISE DATA
Ld HL, NN	21 00 10	FAULT ROUTINE
OUT (c), A	ED 79	INDICATE WHICH RAM
OUT (n), A	D3 00	INDICATE 'FAULT'
DEC HL	2B	
Ld A, N	3E 00	FLASH BOTH LEDS
CPH	BC	
JRNZ	20 F6	
Ld HL, NN	21 FF 10	
DEC HL	2B	AND REPEAT
CP H	BC	
JRNZ	20 FC	
JR	18 EA	

Listing 2. 6K RAM Test.

Data sheets for a range of Z80A peripheral devices are available from Maplin and are listed below. A charge of 80p per copy applies at time of going to press. Table 4 shows some selected Z80A related books which are available from Maplin.

Z80 Keypad - An Introduction

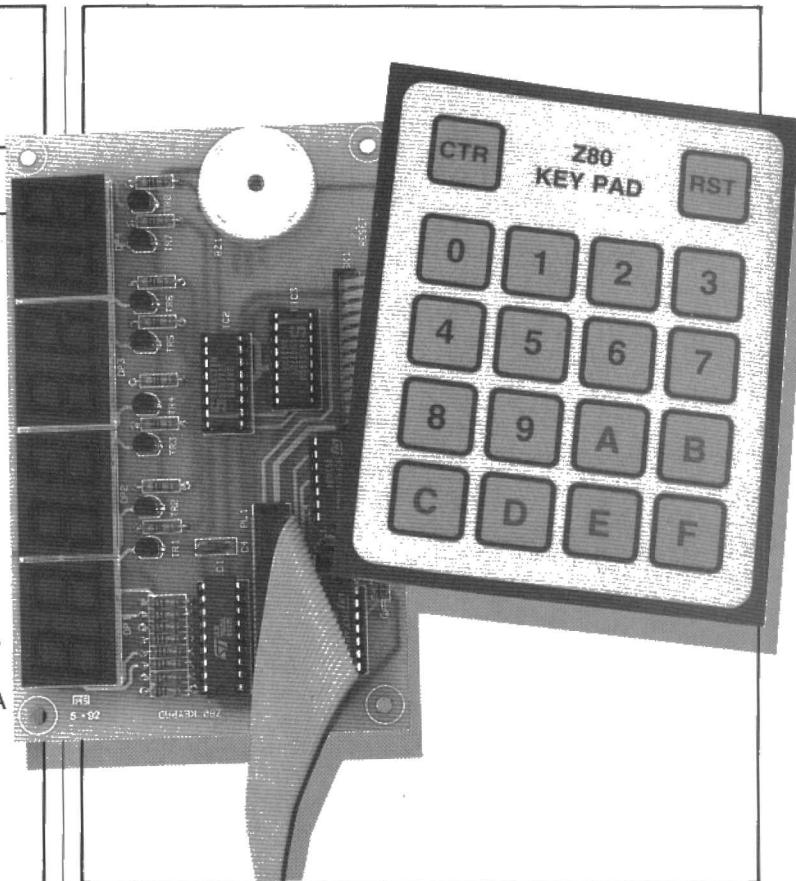
The previously described Maplin Z80A CPU Card offers an inexpensive way to get to grips with computerised control systems for those who can write their own control programs and put them into an EPROM. The provision for 8K of onboard memory is generous for such applications, and input/output decoding for peripheral chips is also provided. To simplify programming, some resident software will be required - it is effectively inaccessible to the user in its basic form. A 'monitor program', resident in EPROM, is available from Maplin for this reason. A keyboard can be added however, and the suggested device is the 8279 programmable keyboard/display interface IC. This device can look after a

variety of input sources (keypads, full keyboards, sensor arrays, etc.) and can control up to sixteen 7-segment displays if required. Thus, it is possible to produce a small computer which can be programmed directly from a HEX keypad, with a 7-segment display to monitor addresses, status and data, both in and out.

In the Z80 keypad module there are eight 7-segment displays. From left to right, the first four form the 'address field', the next two the 'status field', and the two on the right the 'data field'. All that is additionally required is the monitor EPROM to plug into the Z80A CPU Module, and some knowledge of Z80A machine code or the desire to acquire it.

The Keyboard Display Circuit

The circuit is shown in Figure 6 and is really quite straightforward, due largely to the built-in sophistication of the 8279 IC when installed in the Z80A CPU module. The membrane hex keypad, now used instead of the original mechanical switches, communicates with this via the



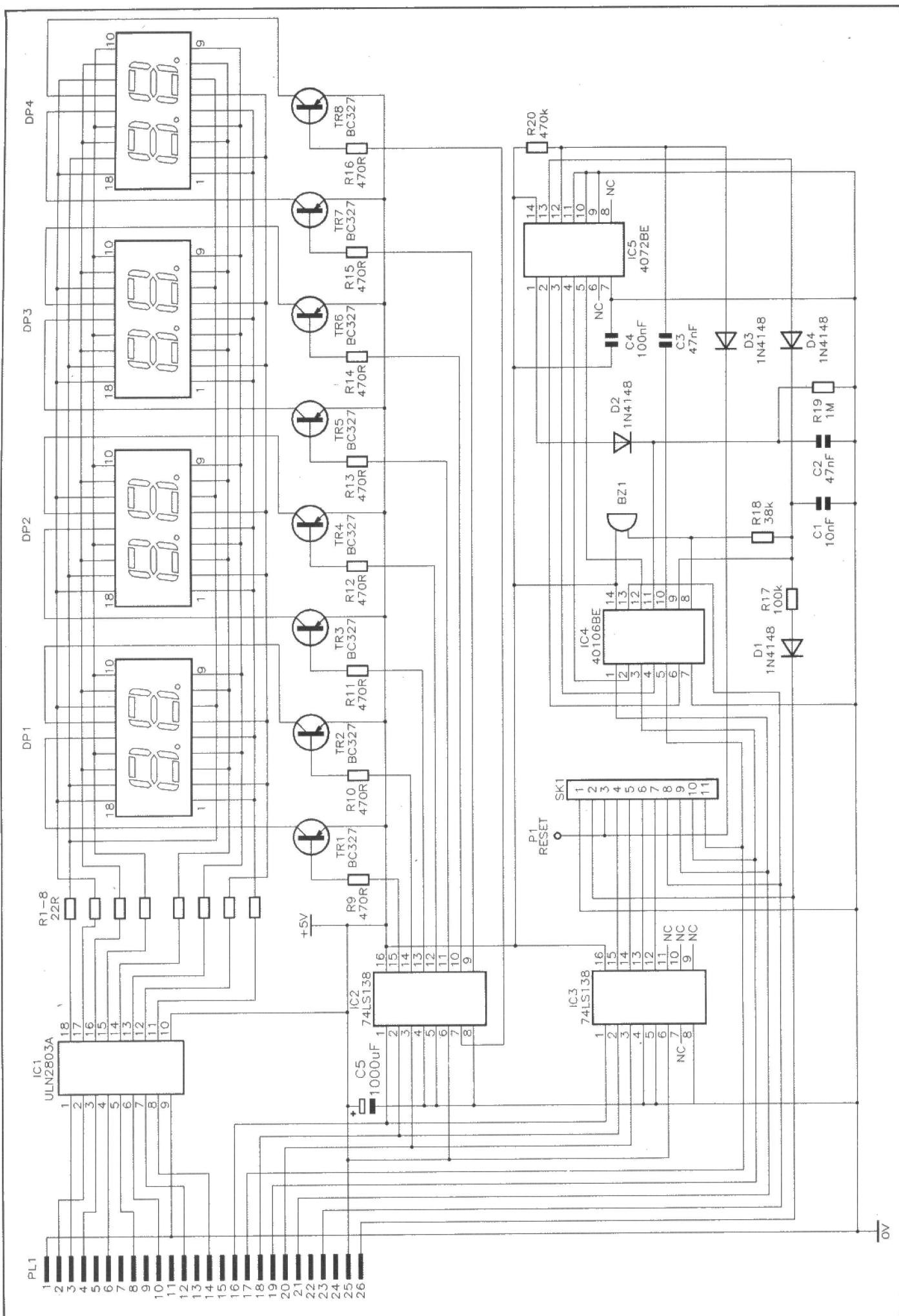


Figure 6. Z80 Keypad circuit diagram.

up to 16 control functions. Some of these are used in the system monitor, described later. The second 74LS138, IC3, is used to 'strobe' four rows of keys (active low), again using the binary count output from the 8279 (SL0 to SL2). The keypad returns four 'column' lines RL0 to RL3, plus CTRL, to the 8279, which examines them to detect a key press and to identify its position in the matrix, derived in conjunction with the number of the currently active row. It then sends an 'interrupt' signal to the Z80A, to initiate a 'read keyboard input' routine.

On their own, membrane keys tend to feel very 'vague' in use (having, in fact, no 'feel' whatsoever), another added feature is the incorporation of a piezo sounder and an oscillator circuit so that there is an audible bleep whenever a key is pressed. This is important with a membrane keypad as there is no positive mechanical action to speak of. To differentiate between normal and control key functions, a warbling tone is produced if the control key is pressed in conjunction with another key. A further feature is that when the unit is first switched on, it produces a power-up indication bleep – as with most PCs, for example. This is also true for the reset function.

pass it to C3. C3 and R20, in conjunction with the second gate of IC5, form a second monostable of the negative-edge triggered type, and it is this that produces the desired bleep duration of each key press. The output from IC5 is taken via D4 to the last inverter stage of IC4, which acts as an oscillator to drive BZ1, with a frequency set by R18 and C1. The frequency is modified by D1 and R17, which are effective whenever the control line is low, producing a different sound. D3 is the reset line and will produce a continuous tone for the duration that the reset key is held down, or for the reset cycle of the CPU.

Construction

No problems should be encountered with PCB construction provided that you negotiate the usual hazards of dry joints, bridged tracks, wrong polarity for ICs and transistors, etc. Refer to the PCB layout in Figure 7 for assembly, and afterwards carry out a visual examination for such defects and check with a meter for shorts across the supply. The same rules of construction as used for the CPU card apply to the keypad – refer to the Constructors' Guide for helpful information if you need it.

If the black edge connector for the

membrane keypad is not already detached from its flat cable as supplied, then remove it by gently pulling the flat cable out of the slot. Insert and solder this connector into the SK1 position, making sure that the side with the row of pins (the pins are offset) faces to the top towards the displays – as shown in Photo 1.

Fit the single PCB pin into the P1 position. To help with insertion press the pin into place with a hot soldering iron. Before soldering the double digit displays (DP1 to DP4) in place, ensure that in each case pin '1' is at the bottom left corner of the legend, and that the device is fully pressed down onto the board. Figure 8 shows the display pinouts as a guide.

When fitting transistors TR1 to TR8, please note that they must not stand higher than the displays above the PCB. In addition, C1 (10nF metallised polyester) should be fitted as close as possible against the PCB, to avoid fouling the ribbon cable when the board is fitted to the lid of the optional case. Note that the leads of C5 (1000μF electrolytic) should be bent over by 90°, so that the component's body rests flush against the PCB. Bending of the leads should be done before inserting and soldering them in place – make sure you bend them the

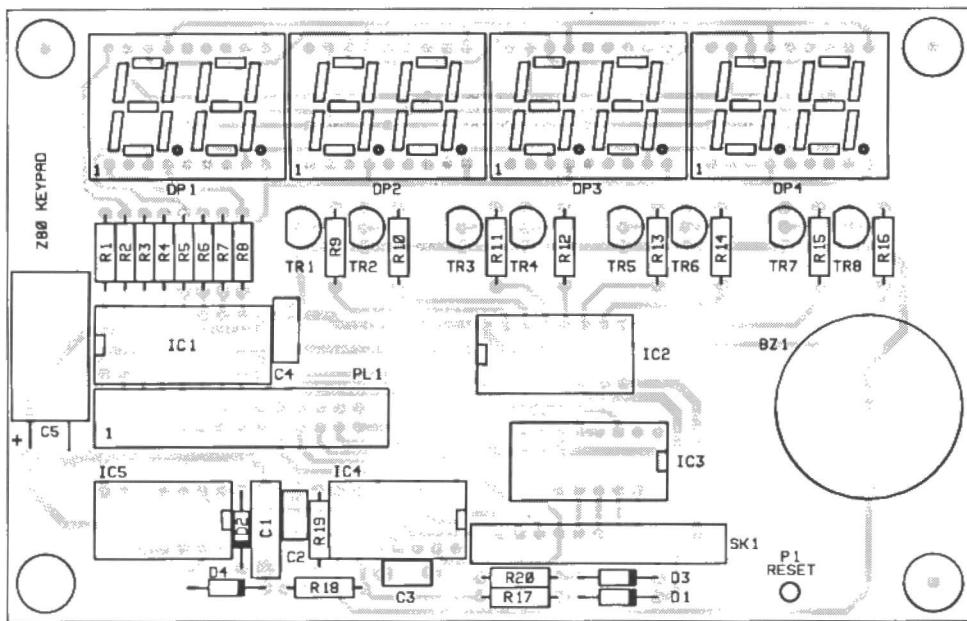


Figure 7. Z80 Keypad PCB layout.

The Bleep Circuit

The four active-low 'column' lines from the keypad are inverted using the first four inverter stages of IC4. The now active high outputs of these are connected to the first OR gate of IC5, which is a 4072BE having two 4-input OR gates in a single package. The output of IC5 will go high if any key line is low. It is passed to D2, C2 and R19, which together act as a simple, non-inverting, retriggerable monostable. This serves to lengthen the pulses of the multiplexed signal, so that overlap produces a continuous key-down signal.

A further inverter in IC4 (pins 10 to 11) is then used to invert this signal and

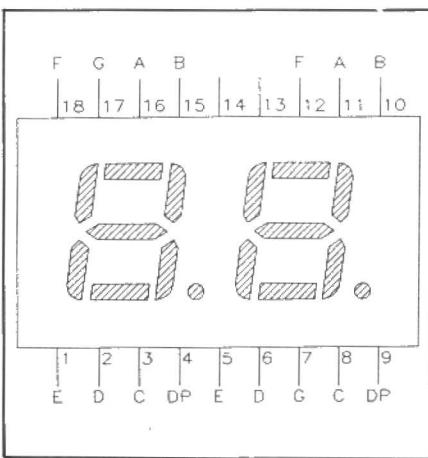


Figure 8. Display pin-out.

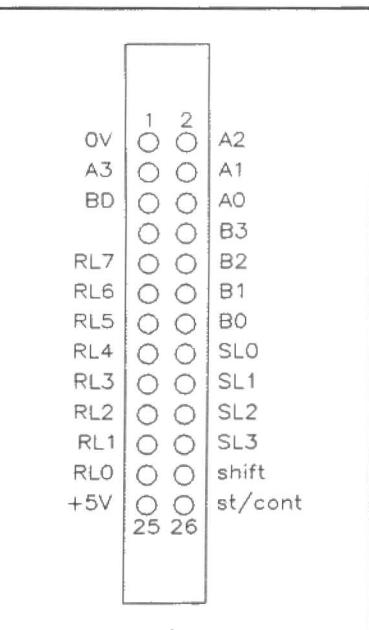


Figure 9. PL1 connections.

right way; after all, C5 is a polarised component!

Initial Testing

By doing resistance checks with the power off will give some indication if all is well, or not. Where there are semiconductors in circuit, the reading will be different depending upon which way round the meter leads are applied to the circuit.

For example, a measurement between the 0V line and any of the lines A0 to A3, and B0 to B3, should show high resistance one way and approximately 22Ω the other way. Similar results should be obtained between 0V and the lines SL0 to SL2, but an open circuit should be

DRILLING DETAILS FOR BOX LID

NOTES

All dimensions are in mm
and taken from outside of lid
Remove burrs and sharp edges

Hole Data
A = $\varnothing 3$ mm
B = Existing holes

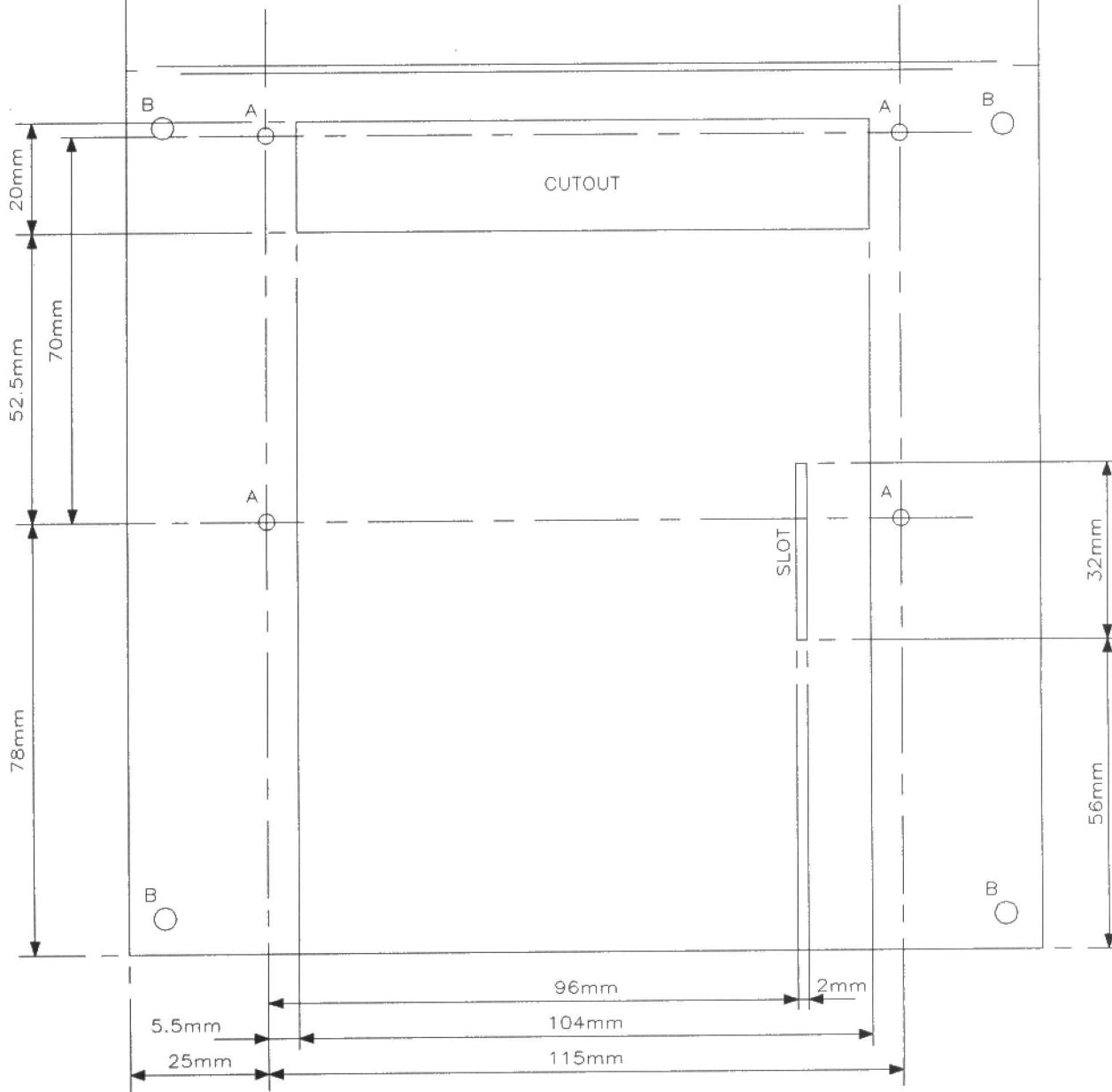


Figure 10. Case lid drilling details.

registered between RL0 to RL3 and 0V – until a key is pressed, at which point the results should be much the same as for the others.

These are all static tests i.e. they are carried out with the chips in place, but with no supply connected. In addition, there are all of the usual visual checks.

Lastly, install the IDC cable loom (optional item) by fitting and soldering the IDC header in position PL1 of the keypad PCB. The cable must exit downwards over IC5. The red stripe on the cable identifies the pin 1 connection as marked on the legend. The cable loom connects the CPU and keyboard/display modules together (pin-out connections are shown in Figure 9).

A Case in Point

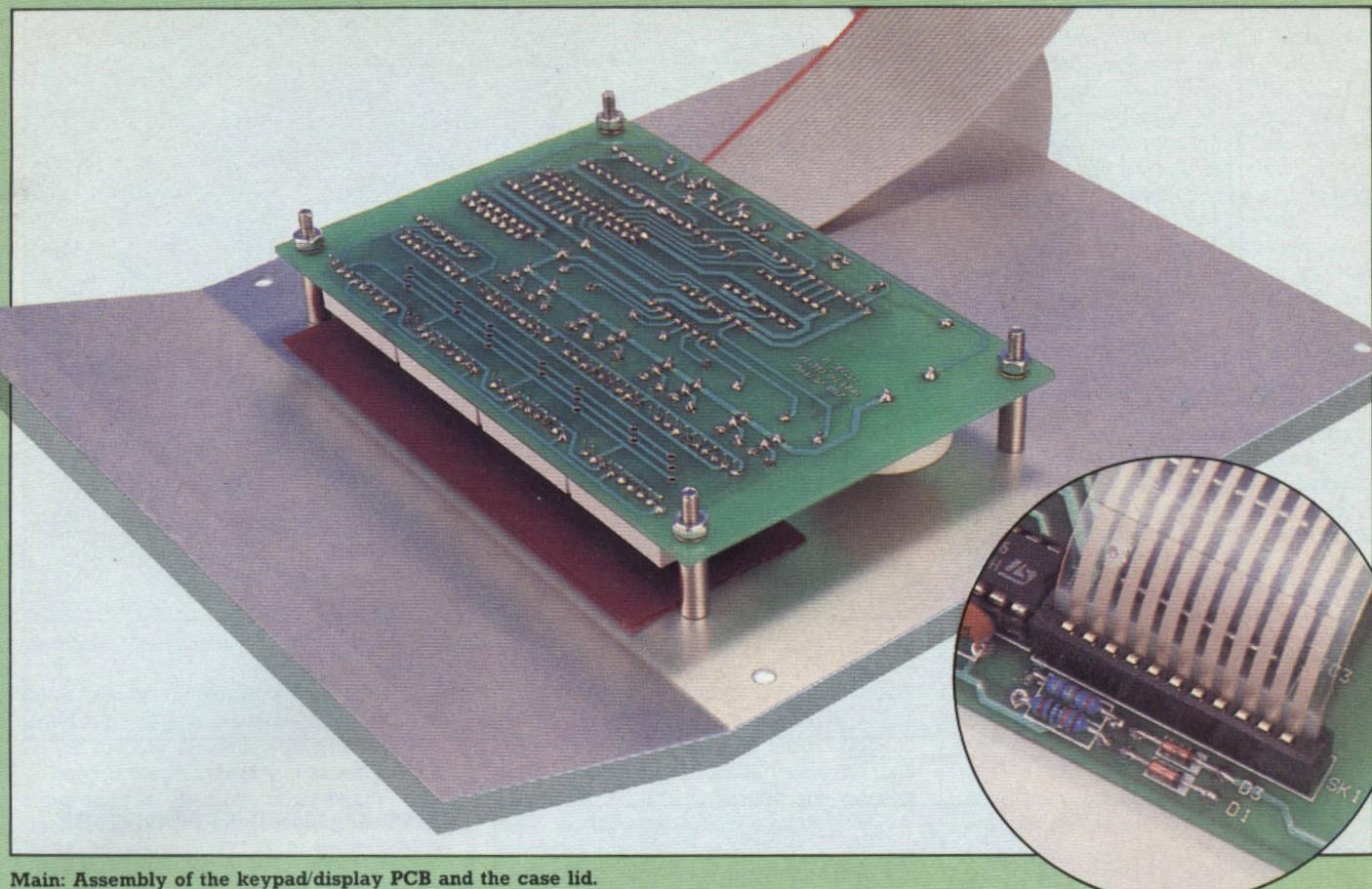
If the optional box is chosen, then Figures 10 to 14 show the drilling information necessary to install both modules. Figure 10 details the lid drilling; the Keypad Module PCB is mounted using the four holes 'A', as shown. A rectangular cut-out must also be provided for the 7-segment displays, as well as a 2mm wide slot which will coincide with the right-hand edge of the membrane hex keypad and carry the keypad's flat cable into the interior of the case.

Installing the Keypad in the Lid

Once these operations have been com-

pleted, you can mount the hex keypad module onto the lid; see Figure 11. Firstly, fit the four M3 x 25mm panel screws, secured by the $\frac{1}{4}$ in. threaded pillars beneath. Trim the red display filter to a size that will clear the top pair of pillars. It can now be secured over the display cut-out on the underside of the panel with a suitable adhesive and left to dry. Don't forget to remove the protective film from both sides of the filter first – the matt side usually faces the displays (to prevent reflections).

Next, attach the membrane keypad to the topside of the lid. Insert the flat cable all the way through the slot and locate the pad squarely on the panel. A pencil or similar can be used to outline



Main: Assembly of the keypad/display PCB and the case lid.
Inset: Close-up of the keypad ribbon cable and connector.

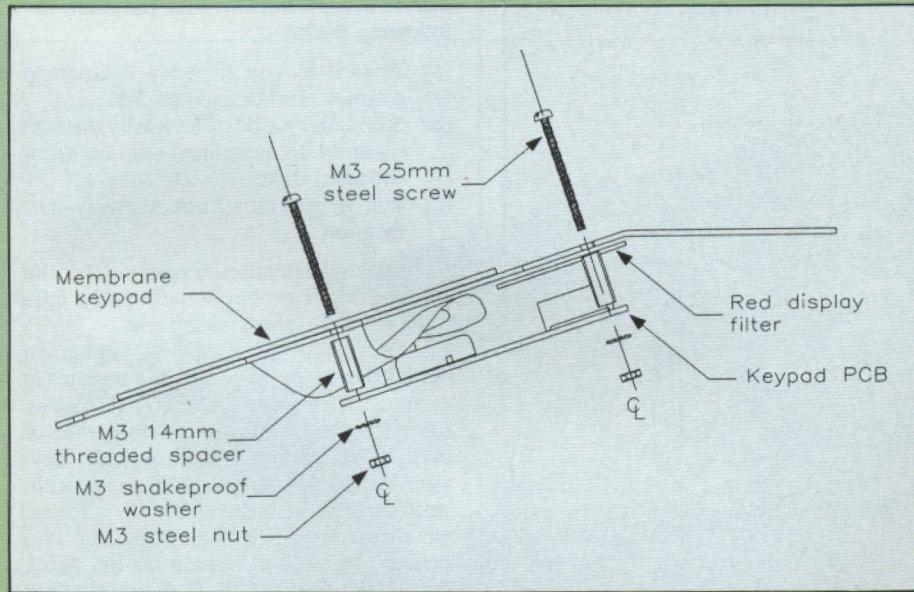


Figure 11. Mounting details for Z80 Keypad.

the exact position, before you peel off the backing layer from the self-adhesive membrane keypad. It can then be pressed down into position. Note that the keypad is designed so that the ribbon cable will not be noticeable after installation – bear this in mind before sticking it down.

'Test fit' the keypad PCB over the four protruding screws and onto the $\frac{1}{2}$ in. pillars, and ensure that the displays are orientated correctly and that nothing is fouling any of the components on the board. Now comes the fiddly bit. You must now contrive to attach the flat conductor to its socket, SK1. Remove the PCB and carefully insert the flat cable into

SK1. It is the correct way round when the bared, flat conductors are touching the socket's contacts; if located the other way then the conductors will be insulated by the plastic backing.

The PCB must then be returned to its final position on the mounting pillars, by carefully folding and twisting the flat cable until the board seats properly. It requires two angled bends in the flat cable to achieve this, but avoid creasing it! Secure the PCB with four M3 nuts and shakeproof washers.

Installing the Z80A Card

The Z80A CPU Card is mounted in the bottom and its edge connector made

accessible through the rectangular cut-out in the rear of the base. Dimensions and positioning of the cut-out are shown in Figure 12. Note, from the drilling details of Figure 13, that for one end of the PCB, cooling slots are used for mounting the $\frac{1}{4}$ in. stand-off pillars. Plain M3 washers must be used on either side of the case material to maintain mechanical stability – 20mm M3 bolts are used to hold the CPU card in place. In addition, an M3 washer is placed under each of the two pillars at the other end so that the PCB is held level in the case – this is important, as the card's PCB edge connector is accessible from the rear of the case. For your convenience, mounting details are reproduced in the side view of Figure 14.

Operation of the System

When power is applied, the Z80A sends clock pulses to the 8279 IC which then generates the scan pulses on lines SL0 to SL2. These can be detected by using a logic probe in the 'pulse' mode. Naturally, on power-up the display could show almost anything – unless the optional monitor ROM (see later) is fitted, in which case (if all is well), you'll see eight dots telling you that the monitor is running. Pulse trains should also be found on pins 7 and 9 to 15 inclusive of IC2 (and hence on the bases of TR1 to 8), and on pins 12 to 15 of IC3. Pressing a key in any of the four vertical rows causes pulses to appear on RL0 to RL3 respectively. Both CTRL and RESET should send a logic low along the reset line to the CPU card when pressed.

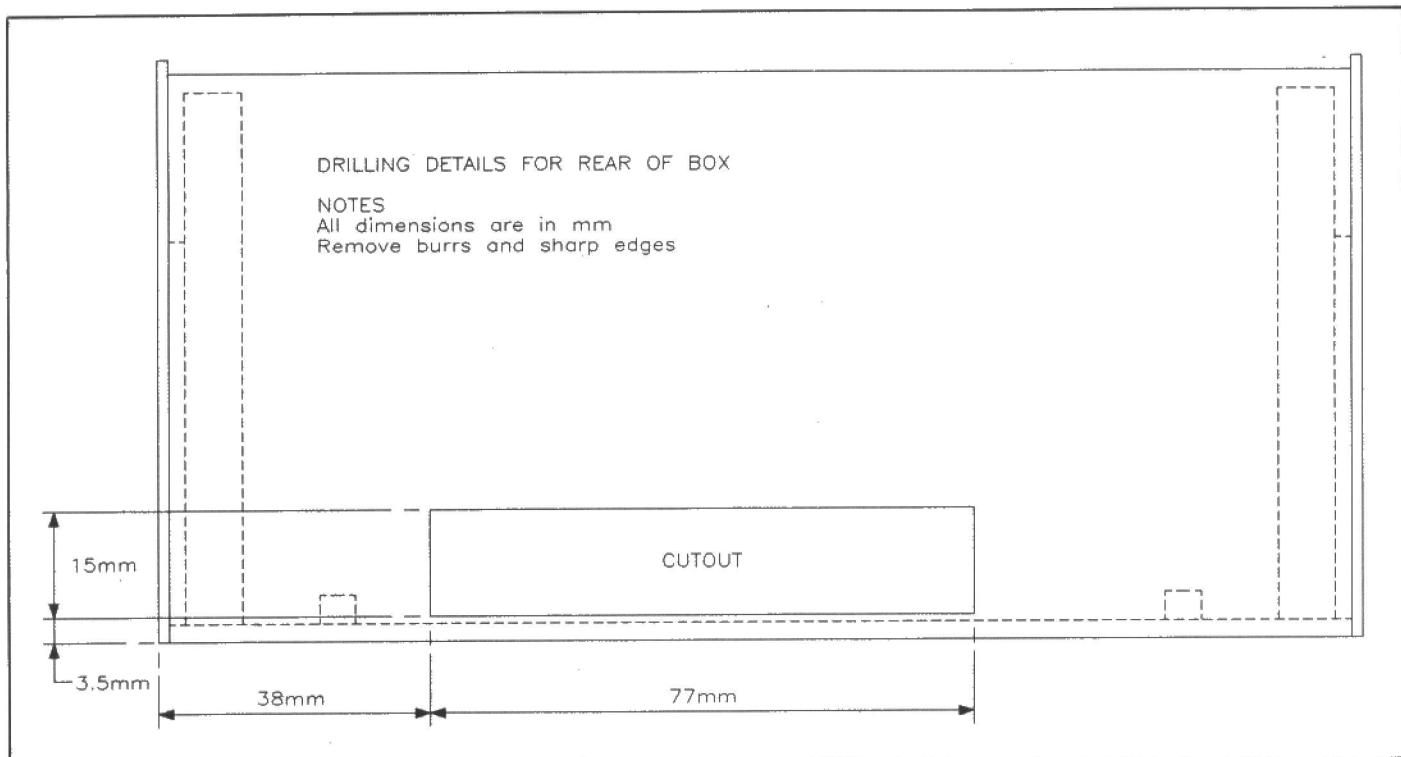


Figure 12. Edge-connector cut-out details, for rear of case.

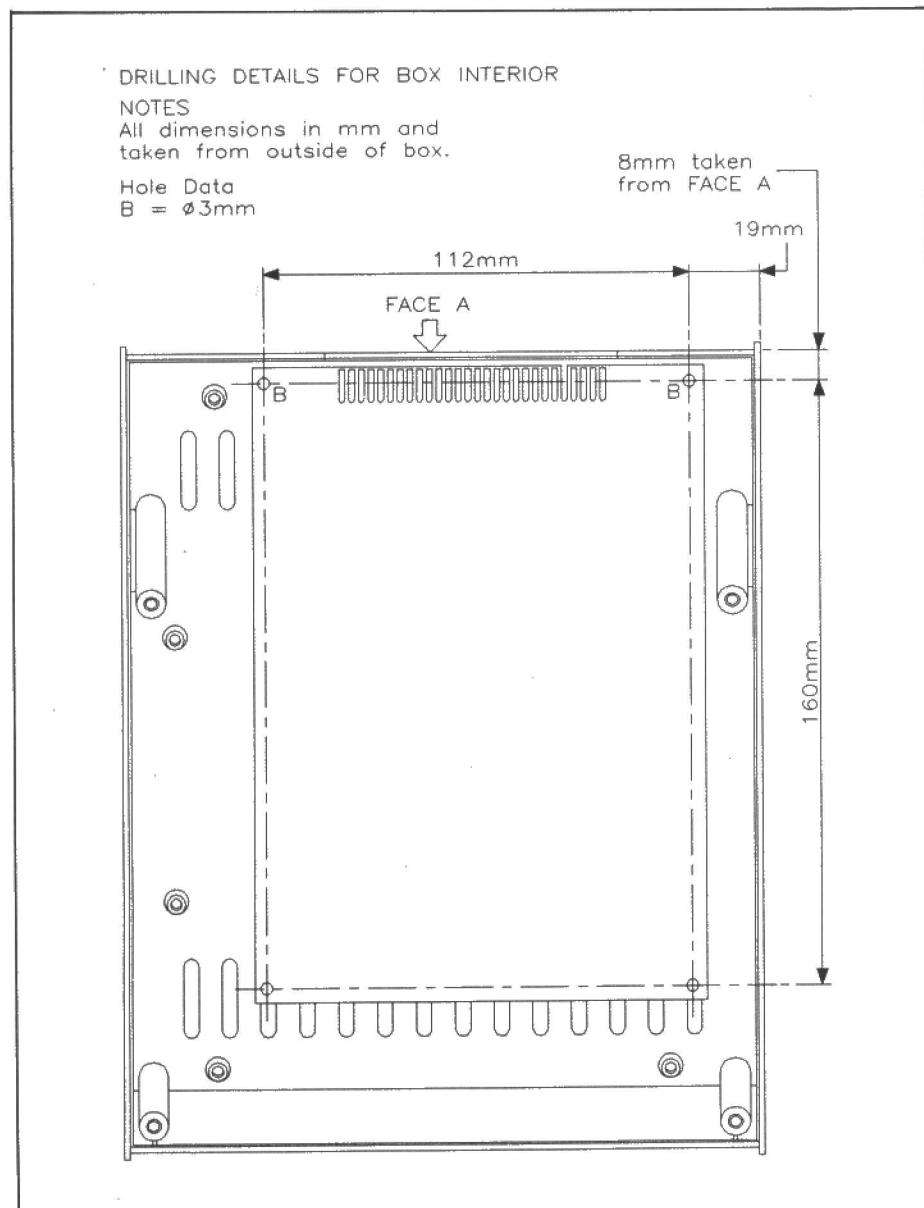


Figure 13. Internal drilling details for case.

The Optional Monitor EPROM

This simple monitor, which is fitted in socket IC10, occupies rather less than half of a 2716 EPROM and provides the following facilities:

- Access to any memory location to examine and/or modify data,
- Step backwards or forwards through memory to examine, edit or enter program data,
- Run a program from a given start location.

No sophistication is claimed for the monitor, but it is easy to use with a little practice. It operates as follows:

On power up, eight dots appear on the display to indicate that the monitor is running. Now press CTRL-A ('CTRL-A' refers to the simultaneous operation of both CTRL and A keys). 'OA' now appears in the 'status field' to indicate 'address mode'. Type in an address which, as you'll notice, goes into the display 'typewriter' fashion i.e. left entry. If you now enter CTRL-D, the status field changes to Od (data mode), though the dots remain in the data field. However, anything typed on the keypad now will appear in the data field and is entered into memory at the location stated in the address field.

Entering CTRL-F takes you forward to the next location, while CTRL-B takes you back to the previous location. CTRL-F and CTRL-B only operate in data mode and always refresh the display – in other words, an address must be entered first before you can move forward or backward from that location. Entering of programs apart, you can use this facility to simply examine or edit memory. Instead of typing in the actual start address, type in the one 'before it'; enter data mode and then use CTRL-F. This

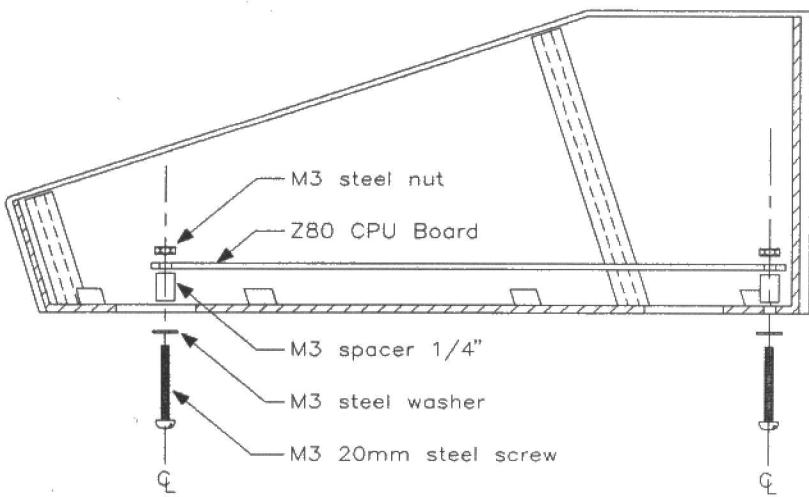


Figure 14. Mounting details for Z80A CPU Module.

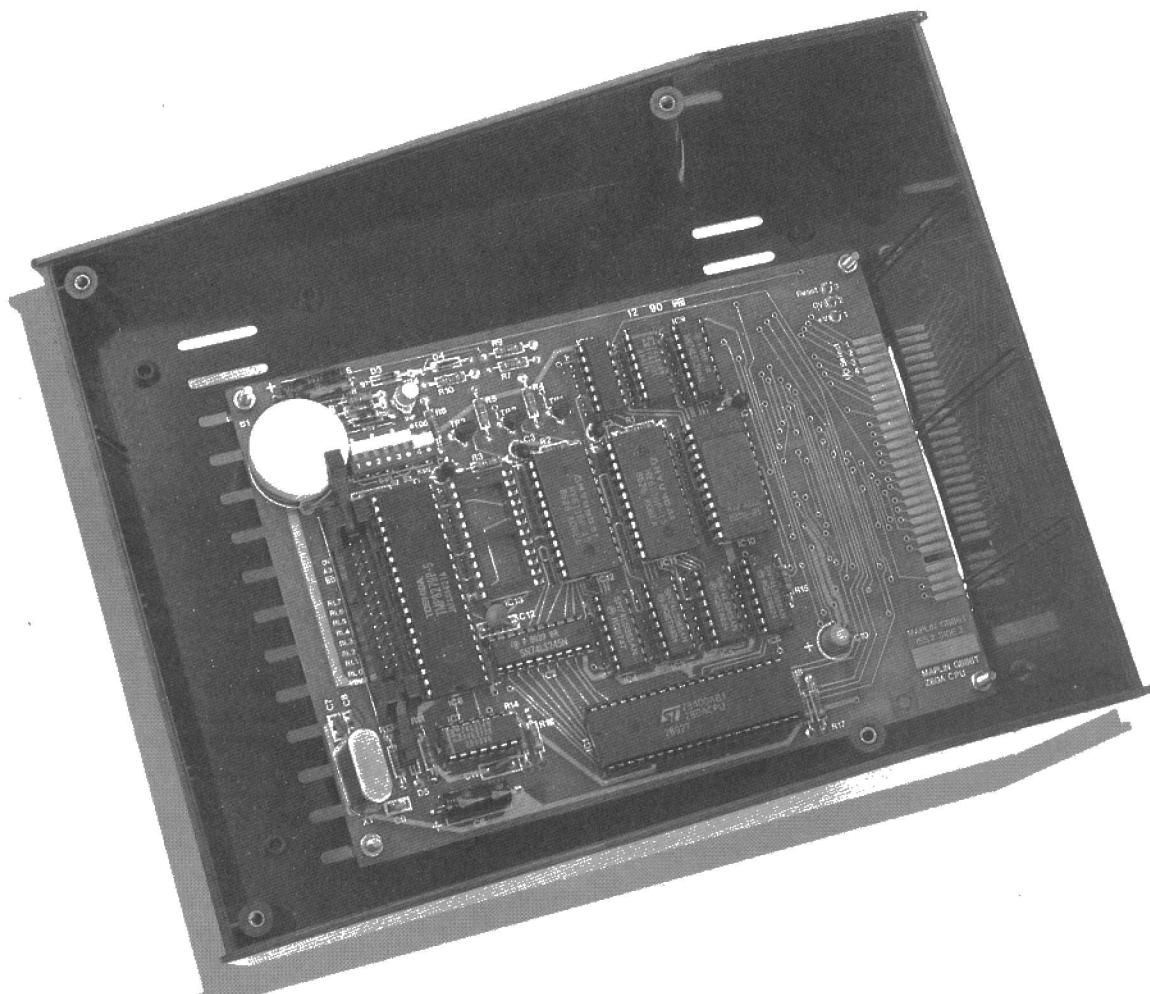
takes you to the location you want and brings up the data actually at that location on the display. Now, as you step forward or back through memory, you will have a simultaneous display of memory and data. You can look anywhere in ROM or RAM in this way. CTRL-A and CTRL-D allow you to 'toggle' back and forth between the two modes, so you can 'nip about in memory quite niftily!'

Note that the data display is only refreshed by CTRL-F or CTRL-B, which means that whenever you toggle back to 'data' mode from 'address' mode the data shown is arbitrary. To see the correct data at the new location, type CTRL-F followed by CTRL-B (or vice versa). Thereafter, any memory locations examined by use of either of the latter control keys is correct.

To run a program that you have entered, type CTRL-E and OE appears in the status field. Enter the start address of the program, and operate CTRL-C. Eight dashes on the display will signify that the program is now running. When a HALT instruction is put at the end of your program, it will pause, you can then leave the program by using the 'reset' keys, which will take you back into the monitor. This, of course, allows you to examine any memory locations that might have been modified by the program simply by re-entering the sequence via CTRL-A.

Scratchpad RAM

As with all monitors, this one requires a small amount of RAM for its own use. It uses this for the storage of variables and also as a 'stack' during the running of certain monitor routines. This scratchpad memory is contained within a 6116 static RAM IC (used in a $2K \times 8$ -bit configuration) installed in socket IC11. The monitor ROM occupies the addresses &0000 to &07FF; the following area of the memory map is normally occupied by RAM, starting at address &0800. The monitor claims the bytes from &0800 to &085F for its scratchpad. This means that the lowest address at which user programs should be stored is &0860. Note that IC positions IC12 and IC13 are available for other $2K \times 8$ memory devices, such as additional 6116 RAMs or 2716 EPROMs already programmed with user software.



The Z80A CPU Card secured into the box.

Z80A CPU MODULE PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2,3,9	100k	4	(M100K)
R4,5,6,10	10k	4	(M10K)
R7,12,13	1k	3	(M1K)
R8	2k2	1	(M2K2)
R11	15k	1	(M15K)
R14	470Ω	1	(M470R)
R15-18	4k7	4	(M4K7)

CAPACITORS

C1-4	100nF 35V Tantalum	4	(WW54J)
C5,6	100μF 10V Axial Electrolytic	2	(FB48C)
C7,8	100pF Ceramic	2	(WX56L)
C9	1nF Ceramic	1	(WX68Y)
C10	100μF 10V Minelect	1	(RK50E)
C11-13	100nF Minidisc	3	(YR75S)

SEMICONDUCTORS

D1	1N4001	1	(QL73Q)
D2	OA47	1	(QH70M)
D3-5	IN4148	3	(QL80B)
TR1-3	BC548	3	(QB73Q)
TR4	BC179	1	(QB54J)
IC1	Z80A CPU	1	(QW00A)
IC2	74LS245	1	(YF91Y)
IC3-6	74LS365	4	(YH11M)
IC7	74LS04	1	(YF04E)
IC9	74LS139	1	(YF54J)
IC14	74LS02	1	(YF02C)
IC15	74LS10	1	(YF08J)

MISCELLANEOUS

S1-4	SPDT Quad DIL Switch	1	(XX29G)
B1	PCB Mounting 3V6 Battery	1	(RK46A)
PCB		1	(GB86T)
DIL Socket 14 pin		3	(BL18U)
DIL Socket 16 pin		5	(BL19V)
DIL Socket 20 pin		1	(HQ77J)
DIL Socket 24 pin		4	(BL20W)
DIL Socket 40 pin		2	(HQ38R)
Pin 2141		1 Pkt	(FL21X)
Instruction Leaflet		1	(XT89W)
Constructors' Guide		1	(XH79L)

OPTIONAL (Not in Kit)

PL1	26 way IDC Header Plug	1	(FJ15R)
	2 x 28-way PC Edge Conn.	1	(FG23A)
X1	2.4576MHz Crystal	1	(FY81C)
IC8	8279 Kbd/Display I/Face	1	(YH51F)
IC10	2716 2K EPROM	1	(QQ07H)
IC11-13	6116 2K CMOS EPROM or 2716 2K EPROM	3	(UF33L) (QQ07H)

TEST COMPONENTS

Ra,b,c,d	470Ω	4	(M470R)
LED1-4	LED Red	4	(WL27E)

Z80 KEYPAD PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1-8	220	8	(M22R)
R9-16	470Ω	8	(M470R)
R17	100k	1	(M100K)
R18	39k	1	(M39K)
R19	1M	1	(M1M)
R20	470k	1	(M470K)

CAPACITORS

C1	10nF Polyester	1	(BX70M)
C2,3	47nF 16V Minidisc	2	(YR74R)
C4	100nF 16V Minidisc	1	(YR75S)
C5	1000μF 16V PC Elect	1	(FF17T)

SEMICONDUCTORS

IC1	ULN2803A	1	(QY79L)
IC2,3	74LS138	2	(YF53H)
IC4	40106BE	1	(QW64U)
IC5	4072BE	1	(QX27E)
D1-4	1N4148	4	(QL80B)
TR1-8	BC327	8	(QB66W)

MISCELLANEOUS

DP1-4	DD Display Type A	4	(BY66W)
BZ1	PCB Piezo Sounder	1	(JH24B)
	DIL Socket 16 pin	2	(BL19V)
	DIL Socket 18 pin	1	(HQ76H)
	DIL Socket 14 pin	2	(BL18U)
	Hex Keypad	1	(ZF52G)
	PCB	1	(GH21X)
	Pin 2145	1 Pkt	(FL24B)
	Instruction Leaflet	1	(XT89W)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

IC10 (CPU Card)	EPROM 2716/M12 (Monitor)	1	(UH87U)
	ABS Console M6007	1	(LH67X)
	Filter Red	1	(FR34M)
	Keypad Cableform	1	(FP63T)
	Double Bubble Sachet	1	(FL45Y)
	Steel Screw M3 x 25mm	1 Pkt	(JY26D)
	Threaded Spacer M3	1 Pkt	(FC38R)
	Isoshake M3	1 Pkt	(BF44X)
	Steel Nut M3	1 Pkt	(JD61R)
	Spacer M3 x 1/4in.	1 Pkt	(FC33L)
	Steel Washer M3	1 Pkt	(JD76H)
	Steel Screw M3 x 20mm	1 Pkt	(JY25C)

The Maplin 'Get-You-Working' Service is available for these projects.

The above items (excluding Optional) are available as a kits, which offers a saving over buying the parts separately.

Order as LK67X (Z80A CPU Module Kit) Price £33.45.

Order as LT15R (Z80A Keypad Kit) Price £24.95.

Please Note: Where 'package' quantities are stated in the Parts List (eg. packet, strip, reel etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately.

Hex Keypad Order As ZF52G Price £8.95.

Z80A Keypad PCB Order As GH21X Price £7.45.

WAVEFORM GENERATOR CIRCUITS

Part 2 by Ray Marston

Ray Marston takes a further look at modern sine-wave generators.

Last month's opening part explained the basic principles of sine wave generation, and then went on to take a detailed look at modern Wien bridge and Twin-T oscillator circuits. Part 2 continues the 'sine wave generator' theme by looking at practical sine wave synthesisers, function generators, and L-C oscillator circuits.

Sine Wave Synthesisers

All the C-R circuits shown last month were oscillator types that gave direct sine wave generation. Sine waves can, however, also be produced by synthesising them from either digital or analogue types of waveform. Figure 1 shows how a sine wave can be created digitally by first building up the rough sine wave shape in a number of digital steps and then removing the digital signal's high frequency components via a simple filter network. Here, a clock signal is fed to the input of a five-stage walking ring or Johnson counter; four of the counter outputs are added together via a resistor weighting network, to produce a crude sine wave which is then converted into a reasonably pure form via low-pass filter C1. The sine wave output frequency is one-tenth of that of the original clock signal; consequently (since digital signals generate only odd harmonics) the lowest harmonic of any consequence to the final sine wave signal are the 9th, 11th, 19th, 21st, and so on, and these are easily removed via C1.

Figure 2 shows a practical 1kHz digital sine wave synthesiser of the above type. It is built around a 4018B CMOS presetable divide-by-N counter, with transistor TR1 used to convert an external 10kHz input signal into a form suitable for clocking the IC. The lowest significant harmonic of this circuit's 1kHz output is the 9th, at -36dB relative to the

fundamental; the sine wave thus has a THD content of about 2%. If a 2nd-order low-pass filter is used in place of C1, all harmonics are reduced to better than 65dB down on the fundamental, giving a THD value of about 0.1%. This circuit thus provides a simple and inexpensive means of generating good-quality sine waves.

Sine waves can also be synthesised from linear 'triangle' waveforms, and a number of manufacturers produce dedicated 'waveform synthesiser' or 'function generator' ICs for this purpose. The best known of these ICs are the ICL8038, available from several manufacturers, and the XR-2206, produced by Exar Integrated Systems Inc. of America. Both of these ICs work in the same basic way, as shown in Figure 3. They contain a combined linear-triangle and square-wave generator that has its frequency controlled by a simple C-R network; the generated triangle waveform is shaped into a sine form via an integral non-linear amplifier. Major advantages of these waveform generators are that the frequency is variable via an external voltage or resistor and a single capacitor,

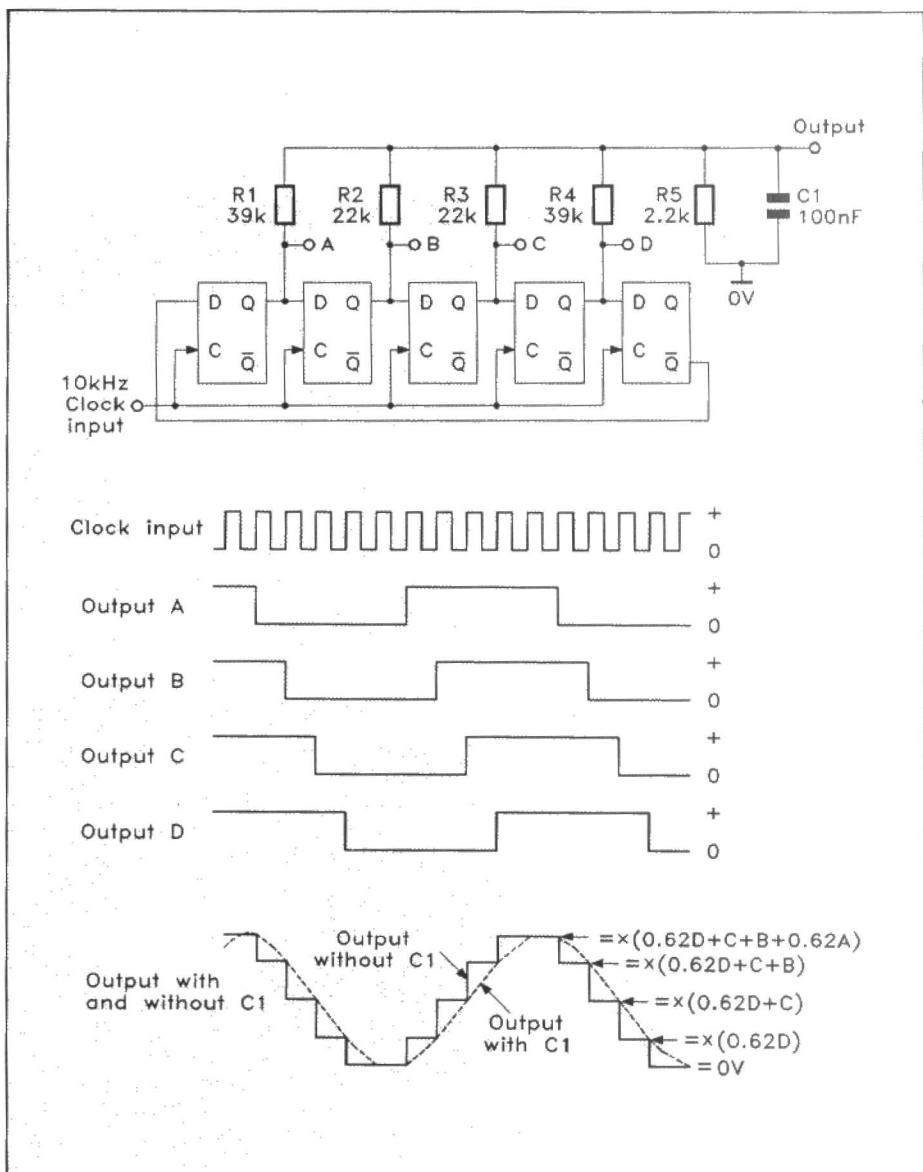


Figure 1. Basic circuit and waveforms of 1kHz digital sine wave synthesiser.

that the frequency can be varied from a fraction of a Hz to hundreds of kHz, and that the waveform is free from 'bounce' (see Part 1). Disadvantages are that the sine waves have typical THD values of 2% in the case of the 8038, or 0.5% in the case of the XR-2206, and that these ICs are fairly expensive.

ICL8038 Basics

The ICL8038 can produce simultaneous sine, square and triangle outputs at frequencies ranging from below 1Hz to above 100kHz. Its output signals can be subjected to frequency sweeping and modulation (FM), and it can be powered via either single-ended supplies in the range 10 to 30V, or split ones in the ± 5 to ± 15 V range. The 8038 is a popular and readily available IC, even though its sine wave output distortion is fairly high.

Figure 4 shows the outline and pin notations of the 8038, and Figure 5 shows the basic way of using it as a fixed-frequency triangle/sine/square waveform generator that is powered via a single-ended supply. Note in this circuit that the pin-7 FM BIAS terminal is shorted to the pin-8 FM SWEEP INPUT terminal, and in this case the 8038's operating frequency is determined by the values of C, R_A and R_B . In fact these two resistors set the operating values for a pair of internal, constant-current generators that alternately charge and discharge the main timing capacitor (C).

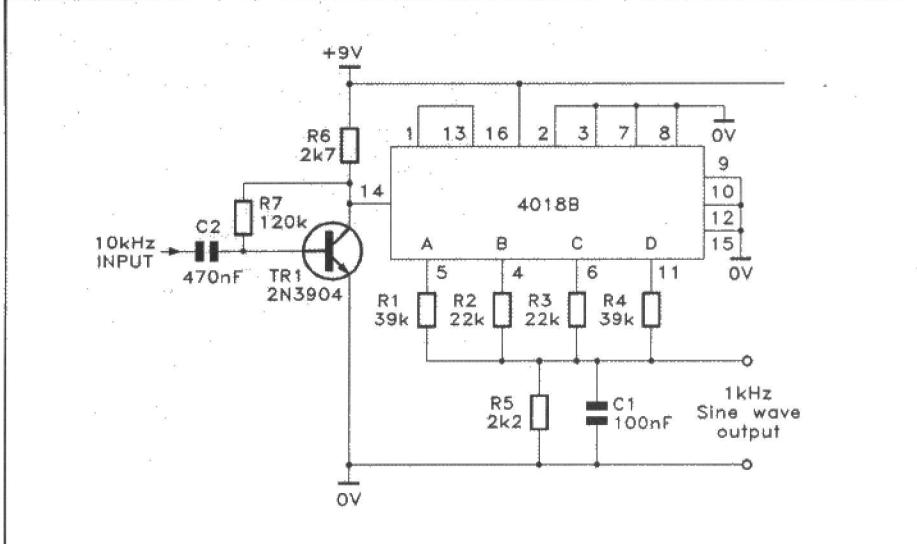


Figure 2. Practical 1kHz digital sine wave synthesiser.

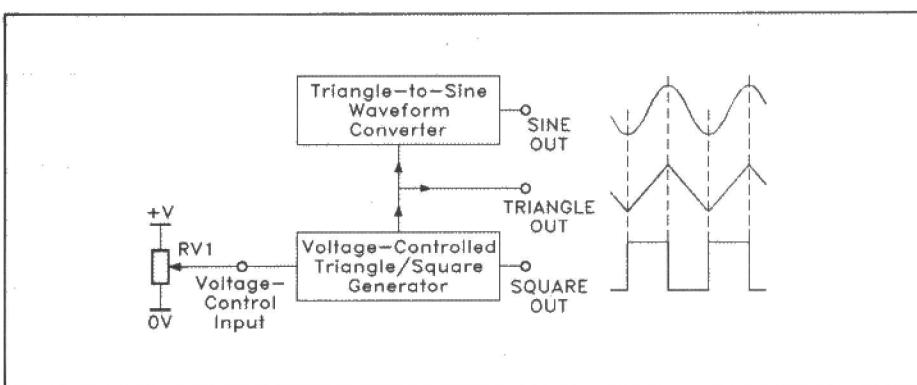


Figure 3. Basic elements of a 'function generator' IC.

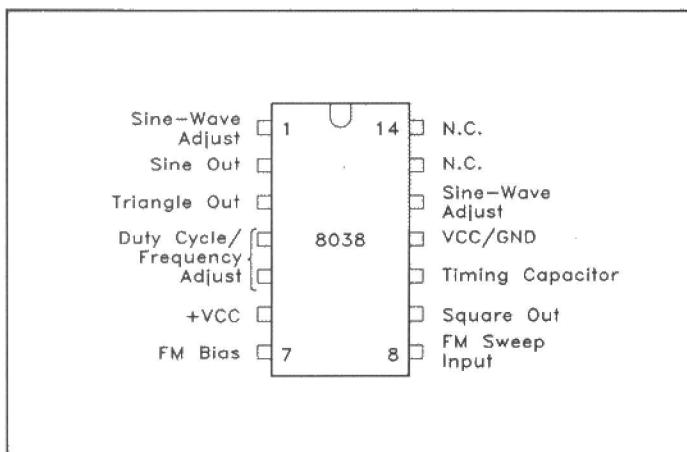


Figure 4. Outline and pin notations of the ICL8038 waveform generator IC.

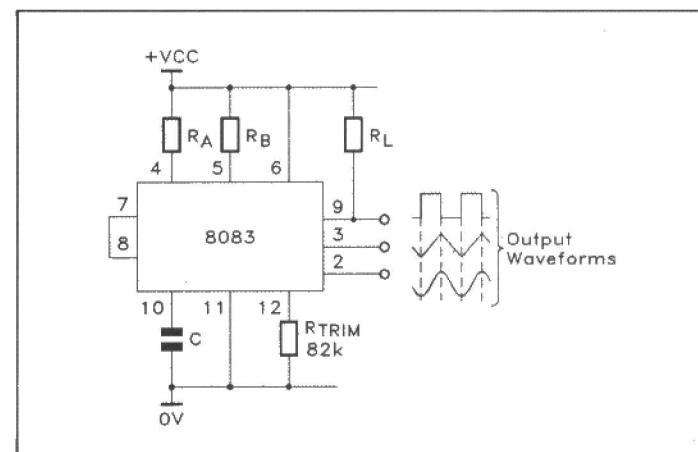


Figure 5. Basic fixed-frequency triangle/sine/square waveform generator.

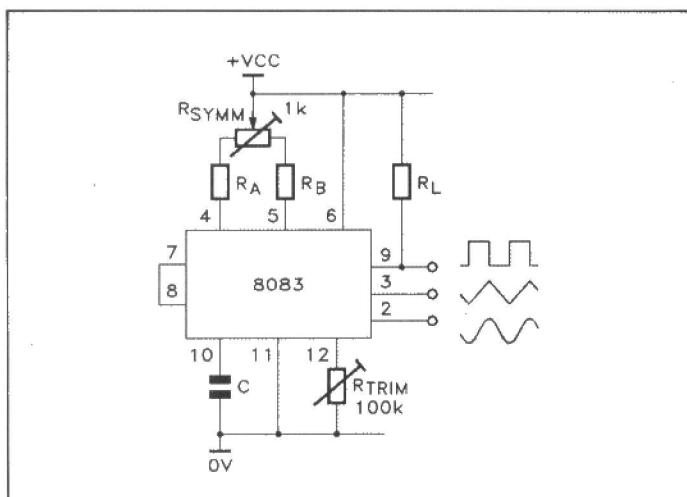


Figure 6. Modified circuit gives perfect symmetry, reduced sine wave distortion.

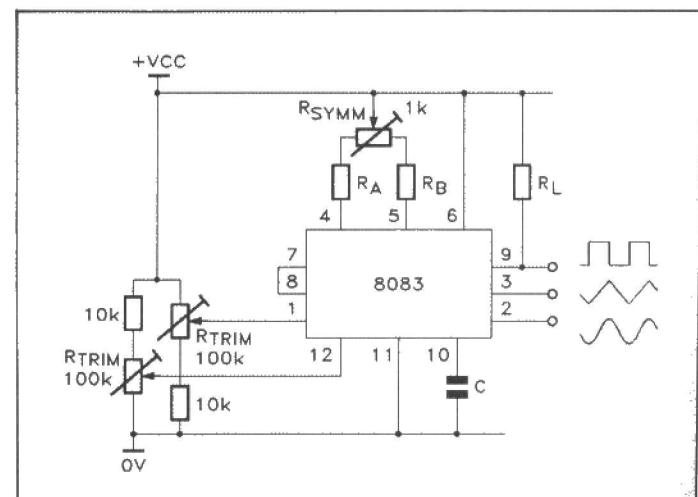


Figure 7. Circuit modified to give minimum sine wave distortion.

The basic action of the Figure 5 circuit is such that, alternately, C is charged linearly at a rate set by R_A until the voltage reaches two thirds $+V_{CC}$, at which point a switching action occurs and C starts to discharge linearly at a rate set by R_B , until the voltage drops to one third V_{CC} . Here another switching action takes place and the whole process is repeated. R_A and R_B can have any values in the range 1k to 1M; if these components have equal values (R) the circuit operates at a frequency of $0.3/(RC)$ and generates a symmetrical linear triangle waveform with a Pk-to-Pk amplitude of $0.33 \times V_{CC}$ on pin-3, and a square wave with a Pk-to-Pk value of V_{CC} on pin-9 (which is loaded by R_L). The triangle waveform is also fed to an internal triangle-to-sine converter, which

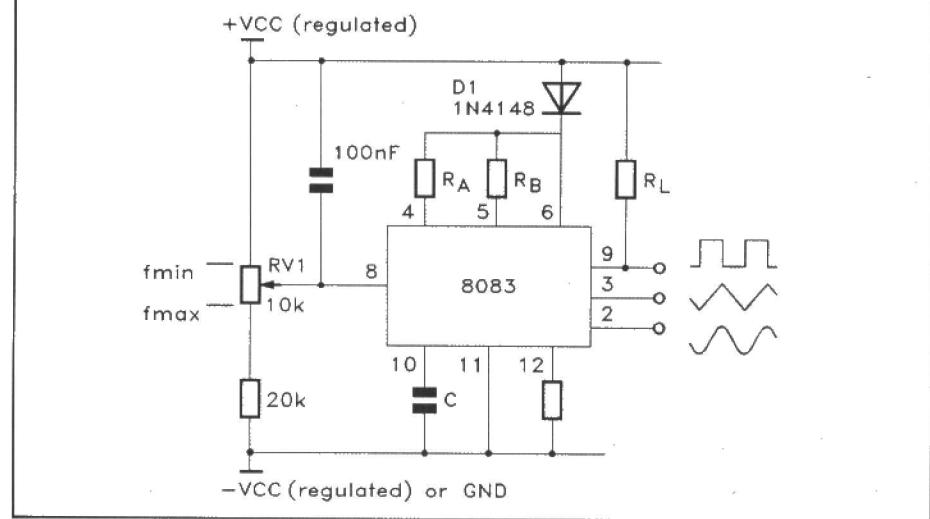


Figure 8. Wide-range variable-frequency waveform generator.

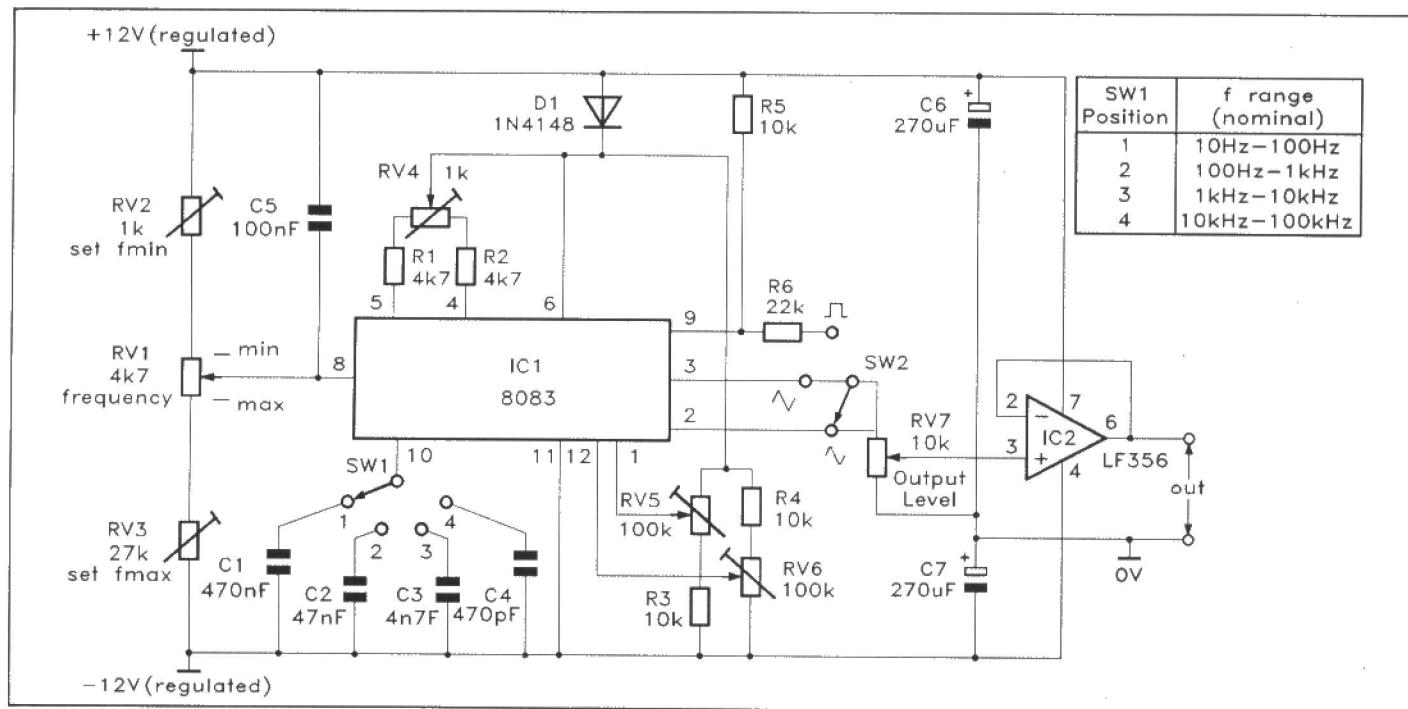


Figure 9. Wide-range sine/triangle/square waveform generator using dual power supplies.

produces a fairly good sine wave output (with a Pk-to-Pk amplitude of $0.22 \times V_{CC}$) on pin-2 when R_{TRIM} is given a value of 82k as shown.

Sine Wave Distortion

The circuit can be made to generate non-symmetrical output waveforms by simply giving R_A and R_B different values. For best sine wave purity the circuit must be set to give perfect waveform symmetry, and this can be achieved by modifying the circuit as shown in Figure 6, which also shows how R_{TRIM} can be made variable and used to trim the sine wave for minimum distortion. In practice, sine wave THD figures as low as 0.8% can be obtained from the Figure 6 circuit when it is used in fixed-frequency applications below 10kHz; the distortion can be reduced even further (to about 0.5%) by further modifying the circuit as shown in Figure 7 and trimming all three variable components for best performance.

Note that the 8083 rarely maintains perfect symmetry when used in variable frequency applications, and in such cases may produce worst-case THD

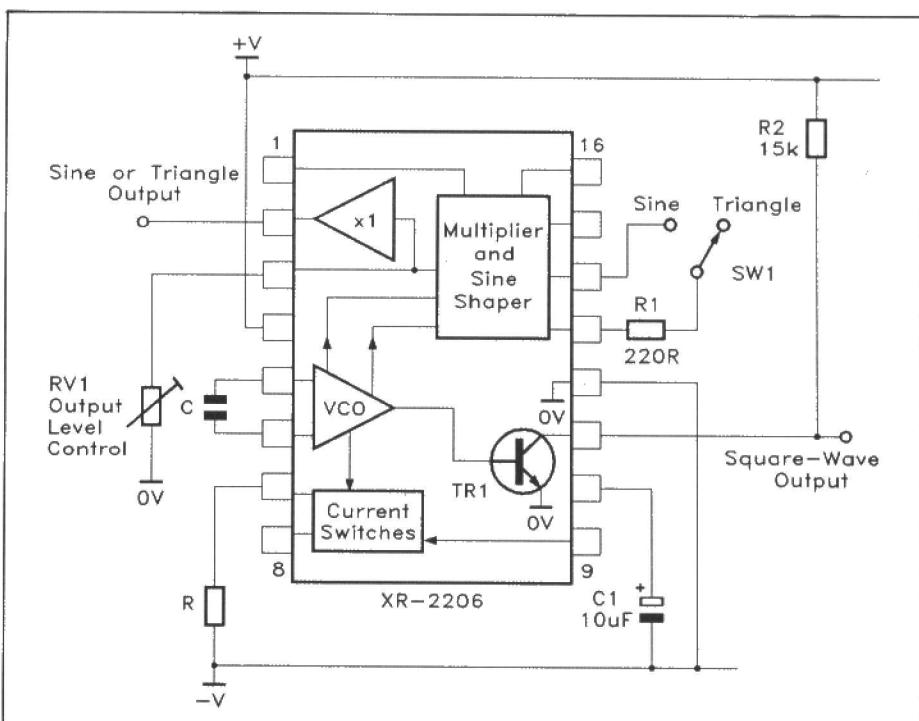


Figure 10. XR-2206 block diagram and basic 'sine/triangle/square' waveform generator connections.

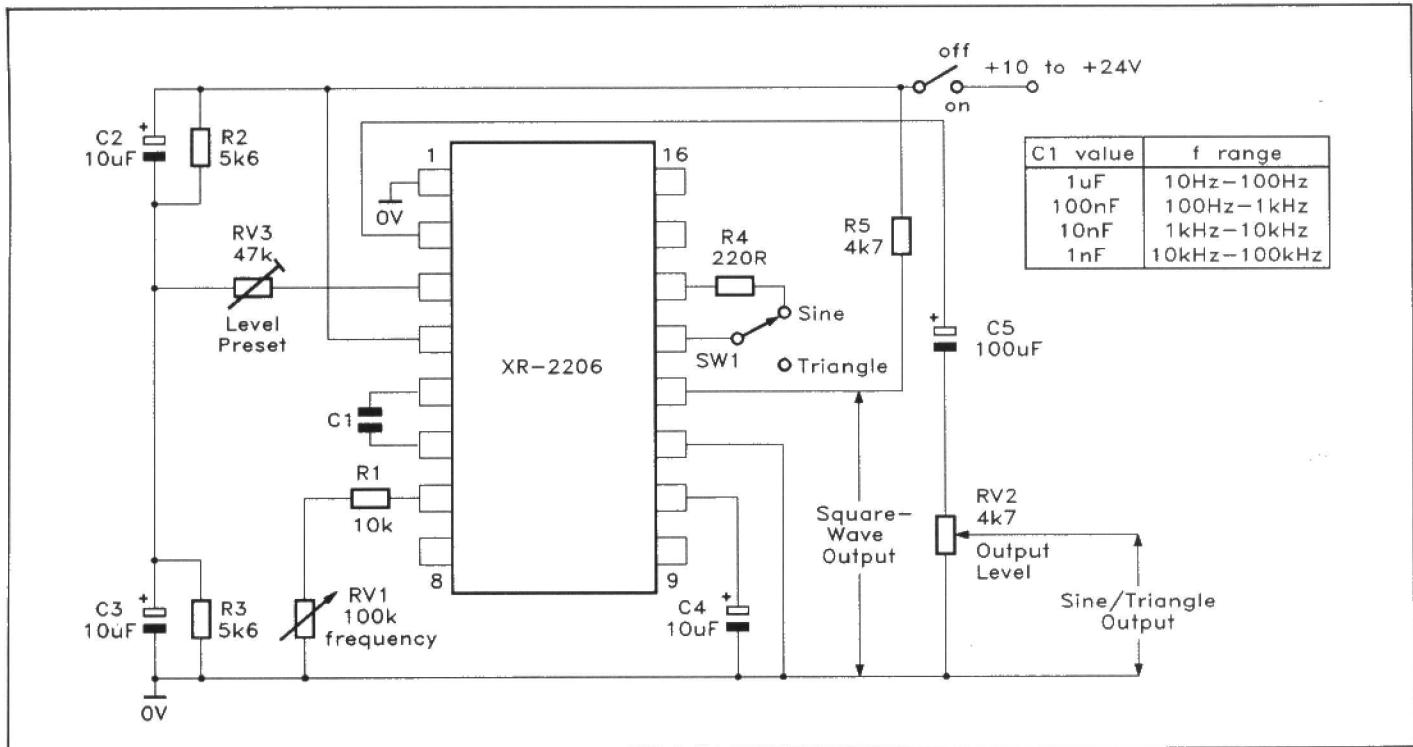


Figure 11. Simple XR-2206-based wide-range sine/triangle/square generator using a single-ended power supply.

figures of several percent; this is the 8038's greatest fault. The IC consumes a quiescent current of about 12mA at 20V and tends to run warm. In most multi-waveform generator applications the user will need to feed the waveforms to the outside world via some type of buffer circuit, so that the desired waveform can be selected at will and made available at variable amplitude levels.

Supplies and Circuits

The 8038 is shown using single ended supplies in the circuits of Figures 5 to 7, and in such cases the three output

waveforms all swing about (i.e., are centred about) the half-supply voltage value. These circuits can be powered via split (dual) supplies by simply using the 'zero' rail as the negative supply line; in this case all output waveforms are centred on the zero or ground line of the split supply. Note that in all cases pin-8 of the IC is susceptible to unwanted signal pick-up, and should be decoupled by wiring a 100nF capacitor between pin-8 and +V_{CC}.

The operating frequency of the 8038 is a direct function of the DC voltage applied between pin-8 and the

IC's positive supply terminal (pin-6). Thus the frequency can be varied or swept by altering this voltage, or can be modulated by feeding a suitable modulation signal to pin-8. An easy way of using the IC as a manually-controlled variable frequency waveform generator is to wire it as shown in Figure 8, with pin-8 connected to a variable control voltage taken from RV1 slider. This voltage is variable from V_{CC} to two thirds V_{CC}; the frequency is at a minimum when the pin-8 voltage equals V_{CC}, and is maximum when it equals (two thirds V_{CC} + 2V). This simple circuit enables the frequency to be varied over

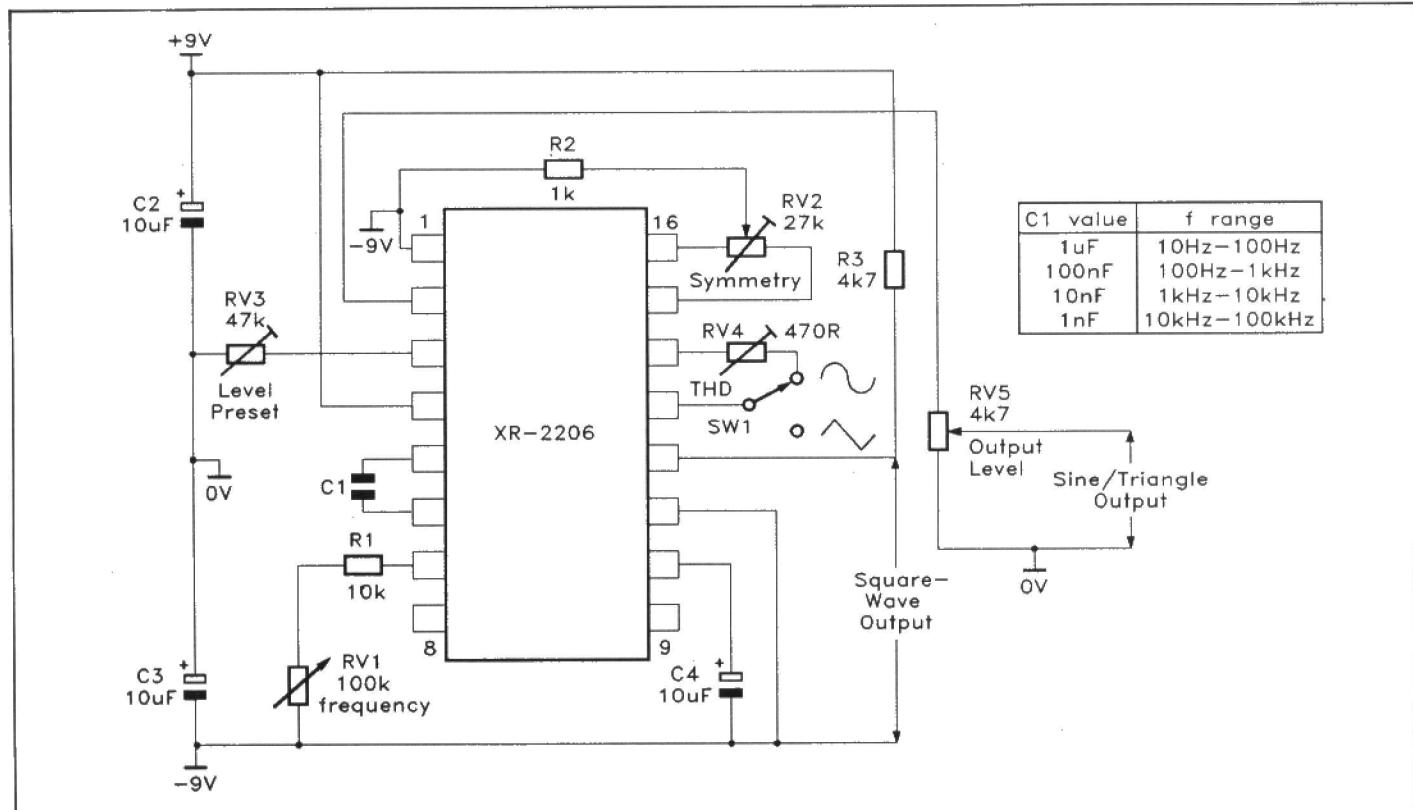


Figure 12. High-performance wide-range sine/triangle/square generator using split power supply.

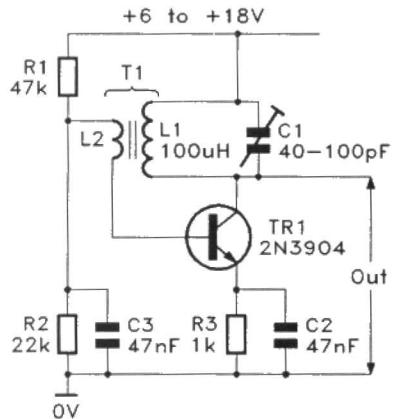


Figure 13. Tuned-collector feedback L-C oscillator.

a range of about 1000:1, but to attain this the highest control voltage on pin-8 must exceed that of pin-6 by a few hundred millivolts, and this is achieved by reducing the IC's pin-6 voltage to about 600mV below $+V_{CC}$ via the forward volt drop of D1. Note that, for optimum frequency stability, this circuit's supply voltages must be stabilised.

To complete this look at the ICL8038, Figure 9 shows how it can be used to make a practical wide-range (10Hz to 100kHz) sine/triangle/square waveform generator by combining the circuits of Figures 7 and 8 and adding an op amp buffer stage (IC2). To set up this circuit, first set RV4 to mid-value and SW1 to range 2, and then trim RV2 and RV3 so that the generator spans the 100Hz to 10kHz frequency range via RV1. Next, set RV1 to give 1kHz output and trim RV4 to give a symmetrical square wave output. Recheck the frequency span range. Finally, reset 1kHz and trim R5 and R6 for minimum sine wave distortion.

XR-2206 Circuits

The XR-2206 is a 16-pin IC capable of generating high-quality sine, square, triangle, ramp and pulse waveforms at frequencies from below 1Hz to hundreds of kHz, using either resistance or voltage control of frequency, and of generating either FM, AM, or FSK forms of waveform modulation. It can operate from either single-ended or dual power supplies. This excellent IC is more expensive and less readily available than the ICL8038. For our present purpose we are only concerned with using the IC in its most basic modes, and with this in mind Figure 10 shows the IC (plus internal block diagram) connected as a simple sine/square/triangle generator that is powered from a dual power supply. The circuit operates as follows.

The heart of the XR-2206 is a Voltage-Controlled Oscillator (VCO), which is driven via a pair of current switches. The VCO's main timing capacitor, C (1nF to 100 μ F), is wired between pins 5 and 6, and its timing resistor, R (4k to 200k), is wired between

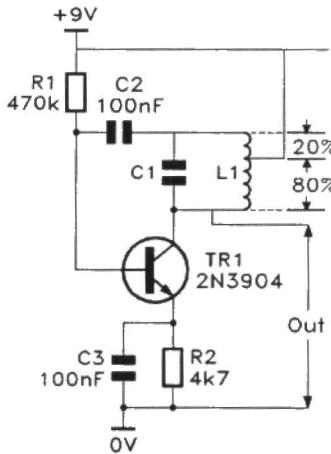


Figure 14. Basic Hartley L-C oscillator.

pins 7 and the negative supply line, and the VCO generates a linear ramp waveform with a frequency of $1/RC$ Hz. When this ramp is rising TR1 is switched on, and when this ramp is falling TR1 is off; a synchronous square wave output is thus available at pin-11 if it is biased high via a 15k resistor, as shown. The actual ramp waveform is fed into the 'multiplier and sine shaper' block and is subsequently made directly available at a high impedance level on pin-3, or in buffered form on pin-2. If pins 13 and 14 are open circuit this waveform is unmodified and appears as a linear ramp, but if a resistance of about 220 Ω (R1) is wired between these pins the 'multiplier and sine shaper' block exponentially reduces the peaks of the input ramp waveform and produces a sine wave output. This sine wave has a typical THD of about 2.5%, but can be reduced to 0.5% by trimming the R1 value.

Figure 11 shows how the above points can be put to practical use to make a simple but useful variable frequency multi-waveform generator that uses a single-ended power supply. The operating frequency is inversely proportional to the values of C and R and RV1, and can be varied from 10Hz to 100kHz in four decade ranges by using the C values shown. The amplitude of the sine/triangle output is fully variable via RV2, but can have its maximum value preset via RV3;

the sine wave THD is typically less than 2.5%.

Figure 12 shows how the above circuit can be modified for operation from dual power supplies, and how sine wave distortion can be reduced to a typical value of 0.5% by adjustment of preset controls RV2 and RV4. These two controls must be adjusted in unison to give minimal distortion when the circuit is first built, and need no further adjustment thereafter. The maximum output level of these circuits can be preset via RV3, which should be set to give a maximum output of less than 2V RMS, to prevent excessive distortion.

L-C Oscillator Circuits

C-R sine wave oscillators are useful for generating signals up to a maximum of several hundred kHz only. L-C oscillators, on the other hand, can generate signals ranging from a few tens of kHz to hundreds of MHz. Figures 13 to 18 show a selection of practical, transistor-based L-C oscillator circuits.

A transistor L-C oscillator consists, in essence, of a simple RF amplifier plus a frequency-selective L-C network that gives appropriate feedback between its output and input. L-C networks have an inherently high 'Q' or frequency-selectivity, so such oscillators produce reasonably pure sine wave outputs, even when the oscillator's loop gain is far greater than unity.

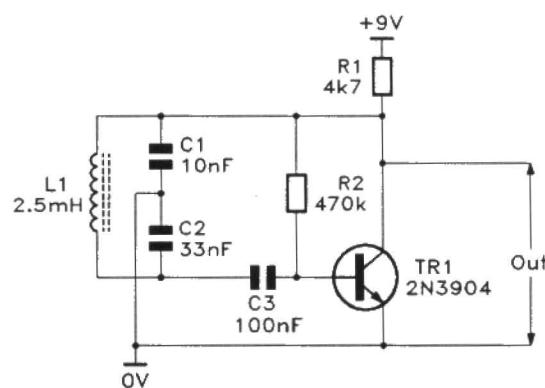


Figure 15. 37kHz Colpitts L-C oscillator.

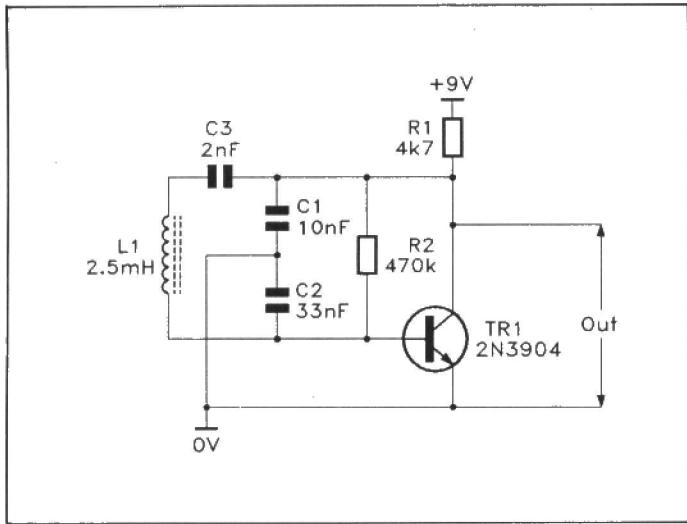


Figure 16. 80kHz Gouriet or Clapp L-C oscillator.

There are many different types of the transistor L-C oscillator. The simplest is the tuned collector feedback type, and an example of this is shown in Figure 13. Here, TR1 is a common emitter amplifier and its base bias is provided via R1 and R2, and emitter resistor R3 is RF-decoupled via C2. L1 and C1 form the tuned collector circuit, and collector-to-base feedback is provided via L2, which is inductively coupled to L1 and thus provides a transformer action. By selecting the phase of this feedback signal the circuit can be made to give zero loop phase shift at the tuned frequency so that, if the loop gain (determined by the turns ratio of T1) is greater than unity, the circuit will oscillate.

A feature of any L-C tuned circuit is that the phase relationship between its energising current and induced voltage varies between -90° to $+90^\circ$, and is zero at a 'centre' frequency (f) given by $f = 1/(2\pi\sqrt{LC})$. The circuit in Figure 13 gives zero overall phase shift and thus oscillates at this centre frequency. With the component values shown, f can be varied from 1MHz to 2MHz via C1, but the basic circuit can easily be modified to operate at frequencies ranging from tens of Hz (by using a laminated iron-core transformer) up to tens or hundreds of MHz.

Circuit Variations

Figure 14 shows a simple variation of the Figure 13 design, the Hartley oscillator. Here, collector load inductor L1 is tapped 20% down from its top end and wired to the circuit's positive supply rail. Thus L1 gives an auto-transformer action in which the signal voltage appearing at the top of L1 is 180° out of phase with that in its low (TR1 collector) end. The anti-phase signal voltage from the top of the coil is coupled to TR1 base via C2, and the circuit then oscillates at a centre frequency set by the L-C values.

Note, from the above description, that oscillator action depends on a 'common signal' tapping point being made into the tuned circuit, so that a phase-splitting auto-transformer action is obtained. This tapping point does not in fact have to be made in the actual tuning coil, but can be made into the tuning capacitor, as in the Colpitts oscillator circuit shown in Figure 15. With the component values shown this particular circuit oscillates at about 37kHz.

Also note in Figure 15 that C1 is in parallel with TR1's output capacitance, and C2 is in parallel with TR1's input capacitance, and changes in TR1 capacitance (due to thermal shifts, etc.) thus cause a shift in frequency. This effect can be minimised (and good

frequency stability obtained) by making C1 and C2 large relative to the internal capacitances of TR1.

A modification of the Colpitts oscillator, known as the Clapp or Gouriet oscillator, is shown in Figure 16. Here, capacitor C3 is wired in series with L1, and has a value that is small relative to C1 and C2. Consequently, the circuit's resonant frequency is decided mainly by the values of L1 and C3, and is not upset by variations in TR1's capacitances. This circuit thus gives excellent frequency stability. with the component values shown, it oscillates at about 80kHz.

Figure 17 shows the basic circuit of a so-called Reinartz oscillator, in which the tuning coil has three inductively coupled windings. Positive feedback is obtained coupling TR1's collector and emitter signals via windings L1 and L2, which are both coupled to L3, and the circuit oscillates at a frequency set by L3 and C1. The diagram shows typical coil-turns ratios for a circuit designed to oscillate at a few hundred kHz.

Finally, to complete this look at basic L-C oscillators, Figure 18 shows how the Figure 13 design can be modified so that it acts as a 465kHz beat-frequency oscillator (BFO) that is 'Varicap' tuned via potentiometer RV1. Here, a standard 465kHz transistor IF transformer (T1) is used as the L-C tuned circuit, and silicon diode D1 is used as an inexpensive varicap diode or voltage-variable capacitor.

When any silicon diode is reverse biased its effective capacitance varies with the applied voltage. It is greatest when the voltage is low, and least when the voltage is high. Varicap diodes are made to exploit this effect, but the ordinary 1N4001 diode can be used for the same purpose, as in Figure 18. Here, C2 (which gives DC isolation between TR1 and D1) and 'capacitor' D1 are wired in series, and the combination is effectively connected across the T1 tuned circuit (since the circuit's supply rails are 'shorted together' as far as AC signals are concerned). Consequently, the oscillator's centre frequency can be varied by altering the capacitance of D1 via RV1.

Next month Part 3 will look at square-wave generator circuits.

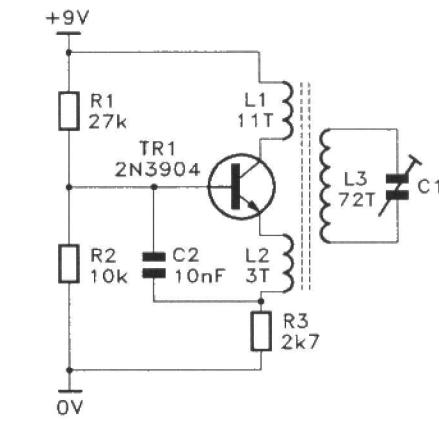


Figure 17. Basic Reinartz L-C oscillator.

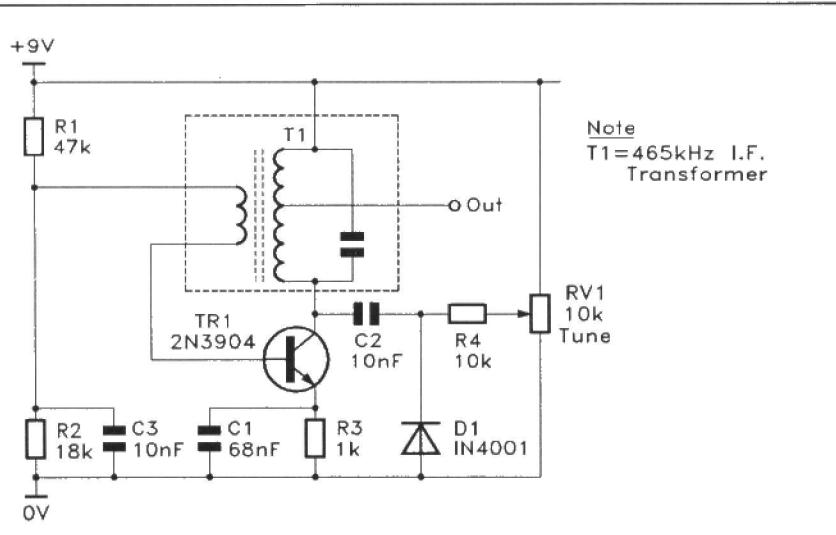


Figure 18. 465kHz BFO with Varicap tuning.

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INTER-NETWORKING

by Frank Booty

The demand for the sharing of information and resources within organisations has been responsible for the rapid growth of the LAN (Local Area Network) inter-connectivity industry in recent years. High capacity LANs have enabled large quantities of data to be shared by local users, while continuing developments in data communications are making it possible for data and resources to be shared across multiple networks.

Often, when extending connections between people and their resources, the LAN technology will already be in place. If wide area networking is involved, the chosen solution will usually be that which offers adequate bandwidth at the lowest cost. (The 'bandwidth' is that of the carrier and determines the baud rate for transfer of data.) However, the most difficult choice that has to be made concerns the equipment which links the LANs together.

An impressive range of inter-networking devices is now available to LAN users, and is dominated by 'bridges', 'routers' and combinations of the two. Here, we will look at the requirements of such inter-networking devices and clarify the features of each technology. Guidelines are also given as to where a particular type of device can be deployed, by drawing on practical experience. The main theme of discussion is the concept of 'open networking', where the emphasis is on producing solutions which meet the requirements. Within this concept, the technologies of bridging and routing can peacefully co-exist in the same network.

REQUIREMENTS OF INTER-NETWORKING DEVICES

The principal reason for the deployment of inter-networking devices is to improve the communications mechanisms in an organisation. This might be to allow more people to share a greater common pool of information, or to make more effective use of computer hardware, or just to communicate with each other. Therefore, inter-networking devices must be able to fulfill the requirement of extending the connectivity of a local network, that is, by coupling it to other local area networks.

Conversely, it must be possible to exercise tight control over the newly extended connectivity. For example, certain types of data in an organisation are considered confidential. Although local security mechanisms, such as password protection, may be applied to sensitive data, an inter-networking device

should be able to prevent unauthorised parties from even attempting to access such data. This enables an additional level of security to be applied and at the same time prevents the available bandwidth being wasted through consumption by unauthorised data.

Any inter-networking device which is selected to provide a service must be able to deliver an acceptable level of performance to its users. Although raw performance figures are readily available for many devices, often it can be difficult to interpret them in relation to applications. Such figures usually relate to the switching ability of a device under extreme conditions; these can be compared to the projected rates of traffic that will be generated.

However, this is only one aspect of performance; where networks are being joined, the interconnection device should ensure that purely local traffic is not exported from one network into another. This requirement is particularly important where two LANs are being connected across a Wide Area Network (WAN), because bandwidth is at a premium.

Further methods for controlling access into other networks should be available, such as filtering out those protocols which have no meaning on other networks. These less obvious performance features will continue to be important. Although new technologies are delivering more WAN services at lower costs, WAN bandwidth is still several orders of magnitude more expensive than the corresponding bandwidth on a LAN, involving as it might communications expenses, compared with the simple coax cable for a LAN.

Having once implemented a service which delivers adequate performance to its users, the service is likely to grow in popularity throughout an organisation. The service will only be fully accepted if it is seen to be reliable, and available for use for a very large part of the time. Therefore, any inter-networking devices must not only be reliable themselves, and engineered to a high quality, but must also provide mechanisms for re-routing around failures anywhere in the network. Where possible, these mechanisms should operate transparently, so that users are completely unaware that any changes have taken place.

Today's LAN technologies, coupled with the range of available wide area networking services, make extended connectivity viable for almost all organisations. Naturally, more powerful inter-networking devices are required to connect into a 'corporate backbone' than for connecting small branch offices. Therefore, devices should be available in suitable shapes and sizes, and thus at cost-effective prices, to closely match the requirement for which they are being installed.

Having reached the point at which inter-networking devices are critical to the everyday business of an organisation, ease of installation and maintenance of the devices becomes a very important consideration. Self configuring devices can be ideal for installations where there is limited technical expertise available.

However, some of the possibilities already discussed can only be realised if highly skilled personnel are able to configure the network and perform any necessary fine tuning. Thus a key

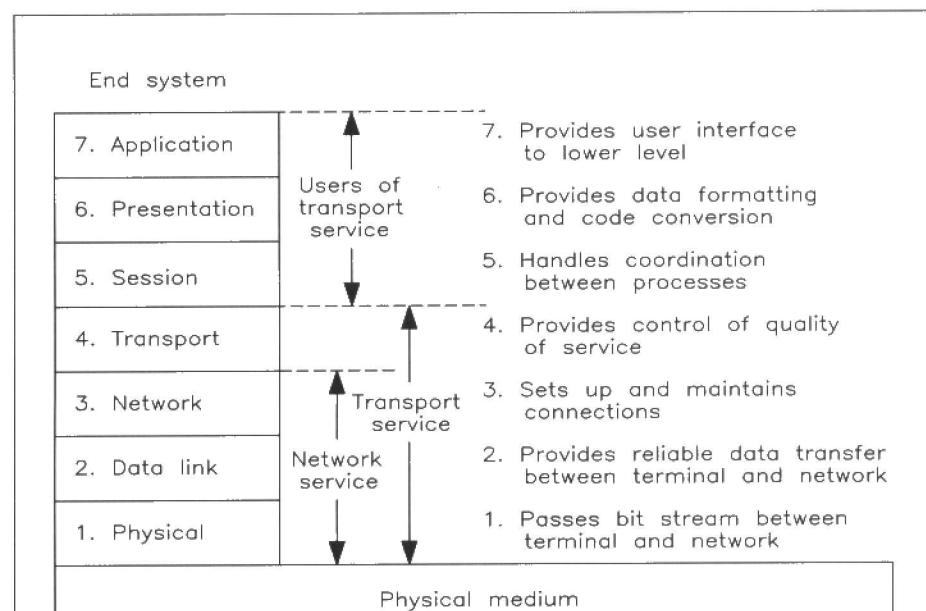


Figure 1. The OSI reference method.

requirement for inter-networking devices is that they should be as easy as possible to install and maintain. Manual configuration of a device is acceptable if it brings additional benefits that an auto-configuring device cannot.

Once inter-networking devices have been deployed, they will need to be managed remotely from one or more control centres. Each device should not only be able to provide information about itself, but it is also ideally positioned to report on events which occur in its local environment. A valuable catalogue of statistics can be accumulated, and used to pre-empt network failures, and for capacity planning purposes. An inter-networking device should therefore be remotely manageable and should also capitalise on its unique position in the network to accumulate useful data.

TYPES OF INTER-NETWORKING DEVICES

Having reviewed the requirements of inter-networking devices, the characteristics of various types of device can now be discussed. These are 'bridges', 'routers' and 'bridge/routers'.

BRIDGE

A bridge operates at layer two of the OSI seven layer model for communications, specifically at the MAC sub-layer (see Figure 1). As such it uses the physical addresses in data frames to keep track of network activity, and it uses frame level information to make decisions about whether to discard or forward each frame that it observes on the network.

Bridges are usually implemented along the guidelines defined by the IEEE 802.1d standard, which enables bridges from different manufacturers to co-exist on the same network, allowing them to participate in true open networking environments.

Bridges are used to connect networks together, allowing data and resources to be shared. They also enable network security to be enforced through sophisticated access controls. A bridge usually achieves this by comparing the physical addresses in a frame against an approved list which has been defined by the network administrator.

Much of the work of a bridge involves dealing with the physical aspects of a network, such as receiving and transmitting frames. A high proportion of its functionality can be implemented in hardware, and so a bridge can deliver a high 'raw' performance level. This high performance is usually complemented by a filtering mechanism, where traffic from one local user to another is not propagated throughout the network by the bridge.

Bridges which conform to the IEEE 802.1d specification use the Spanning Tree Algorithm to ensure that network availability can be maintained if certain nodes or components should fail. The algorithm allows additional connections and bridges to be incorporated into the

network for resilience. It designates an element as being a standby resource, until the failure of another element causes it to become an active resource. The active resources are connected together in a logical tree, so that data loops cannot occur.

Early versions of the Spanning Tree Algorithm only acknowledged the existence of one logical tree throughout an entire network, causing the recovery time for a large network, following a failure, to be prohibitively long. However, with some bridges multiple logical trees may exist in the same network, greatly reducing recovery times and making the network easier to manage.

The simplicity of the Spanning Tree Algorithm can sometimes lead to anomalies in the network, where data from one network to another does not always follow the most direct path to its destination. This can happen because the direct path has been designated as a standby path. On several bridges, this situation is resolved by the implementation of adaptive routing, or 'brouting' algorithms whereby traffic will follow the most suitable route. Devices known as 'brouters' should be considered as bridges with additional options. Brouters can still be considered as part of an open networking strategy, as these options can be restricted to specific parts of the network.

Bridging technology is sufficiently mature for bridges to be found in several different configurations and sizes. There is often a distinction between local bridges and remote bridges. Local devices are used to join LANs in the same building, or to partition an existing LAN for reasons of security or performance. Remote bridges are used to connect LANs over a wide area network service. Remote bridges can also incorporate an error detection protocol over the wide area network, to ensure that data integrity is maintained and to provide a simple means of flow control between the bridges.

The simplicity of the bridging device is perhaps its most valuable feature. A bridge is transparent to higher layer protocols and does not need to understand the detail within a data frame in order to process it. Indeed some protocols are structured in such a way that they have to be bridged, because there is no alternative. A bridge is therefore capable of supporting all applications on a network, irrespective of the protocols being used. This feature also means that no specific configuration of the bridge has to be carried out by the network administrator for each protocol, before it can be used on a network.

Finally, bridges can be managed remotely, using standard protocols and definitions, such as CMIP and SNMP. They can provide useful information about the behaviour of the network at the physical level, and can be included as part of an enterprise wide network management strategy.

Thus a bridge is able to satisfy all of the requirements for an open networking strategy as defined earlier.

ROUTER

A router operates at layer three of the OSI seven layer model for communications, that is the network layer. Unlike a bridge, a router uses the logical addresses in data frames to keep track of network activity, and to make decisions about how to handle data that it receives.

Routers are usually implemented specifically for a given protocol, but multi-protocol routers can simultaneously support the routing of several protocols. Where routers have followed the standards for a specific set of protocols, they can then co-exist with routers from different manufacturers, allowing them to participate in open networking environments.

Routers are used to connect networks together, allowing data and resources to be shared. They also enable network security to be enforced. Where a host computer has several logical addresses sharing one physical address, the router can be more selective than a bridge.

A router has rather more processing to perform than a bridge for each data frame that it receives. It can compensate for the reduction in raw data performance that this brings by making better informed choices as to when and where it should forward traffic. For example, a bridge will forward multicast frames unless it has been configured not to. A router will only forward multicast data which is necessary for the correct operation of the protocol concerned.

The data transmitted by a router does not continue to carry the physical layer addressing, unlike a bridge. This can save a small amount of network bandwidth, but more importantly, allows incompatible physical media, such as 'Ethernet' and 'Token Ring', to be connected.

Each router in a network will regularly monitor the paths in a network, perhaps on the basis of several metrics, such as congestion and priority, as well as availability. This allows the router to choose what it perceives to be the best path for each individual packet of data.

As with bridges, routers can be found in different configurations and sizes. Remote routers can also incorporate an error detection protocol over the wide area network, to ensure that data integrity is maintained, and to provide a simple means of flow control.

A multi-protocol router needs to be configured for each protocol that it is expected to handle. This can be quite complex, and requires a reasonable level of technical expertise. However, the configuration process is necessary if the potential benefits of using a router are to be realised. The host systems in the network also need to be aware of the router. This allows data packages to be directly addressed to the router, enabling the router to exercise flow control during a data packet's journey to its destination. Routers enable network administration to be divided into manageable areas or sub-networks. It can be more convenient to manage several autonomous sub-networks than attempting to manage a single large network. It can also become

inconvenient (to say the least) if taken too far and the network divided into too many sub-networks. Each area network administrator is responsible for the allocation of logical addresses to his user population. A carefully planned strategy should ensure that there is always a plentiful supply of addresses available for new users.

Finally, routers can be managed remotely, using standard protocols such as CMIP and SNMP provided that definitions exist governing the individual protocols that are being routed. They can provide useful information on the behaviour of the network at multiple levels, and can be included as part of an enterprise wide network management strategy.

In summary, it can be seen that a router is able to satisfy all of the require-

ments for an open networking strategy as defined in the first section of this article.

BRIDGE/ROUTER

A 'bridge/router' is a hybrid device which incorporates the functionality of both a bridge and a router. It can apply routing algorithms to those protocols it has been configured to recognise, and it can apply bridging algorithms to all other protocols.

This combination of features enables many bridge/routers to satisfy the requirements of open networking devices.

WHERE TO USE WHICH DEVICE

Bridging must be used in networks where non-routable protocols such as LAT and other proprietary protocols are

being used to provide a service. This may be achieved with pure bridges or with hybrid bridge/routers.

Apart from this, there are no definite rules to be followed as to where bridges should be used and where routers should be used. In general, the simplicity of bridges makes them the preferred choice for smaller and mid-range networks. The ability of routers to provide efficient traffic control and their ability to fit into autonomous local administration procedures makes them attractive devices to attach to fully-meshed corporate 'backbone' networks, as illustrated in Figure 2.

This is becoming increasingly recognised in large corporate networks, where a powerful multi-port bridge/router brings the users from an entire administrative domain or geographical

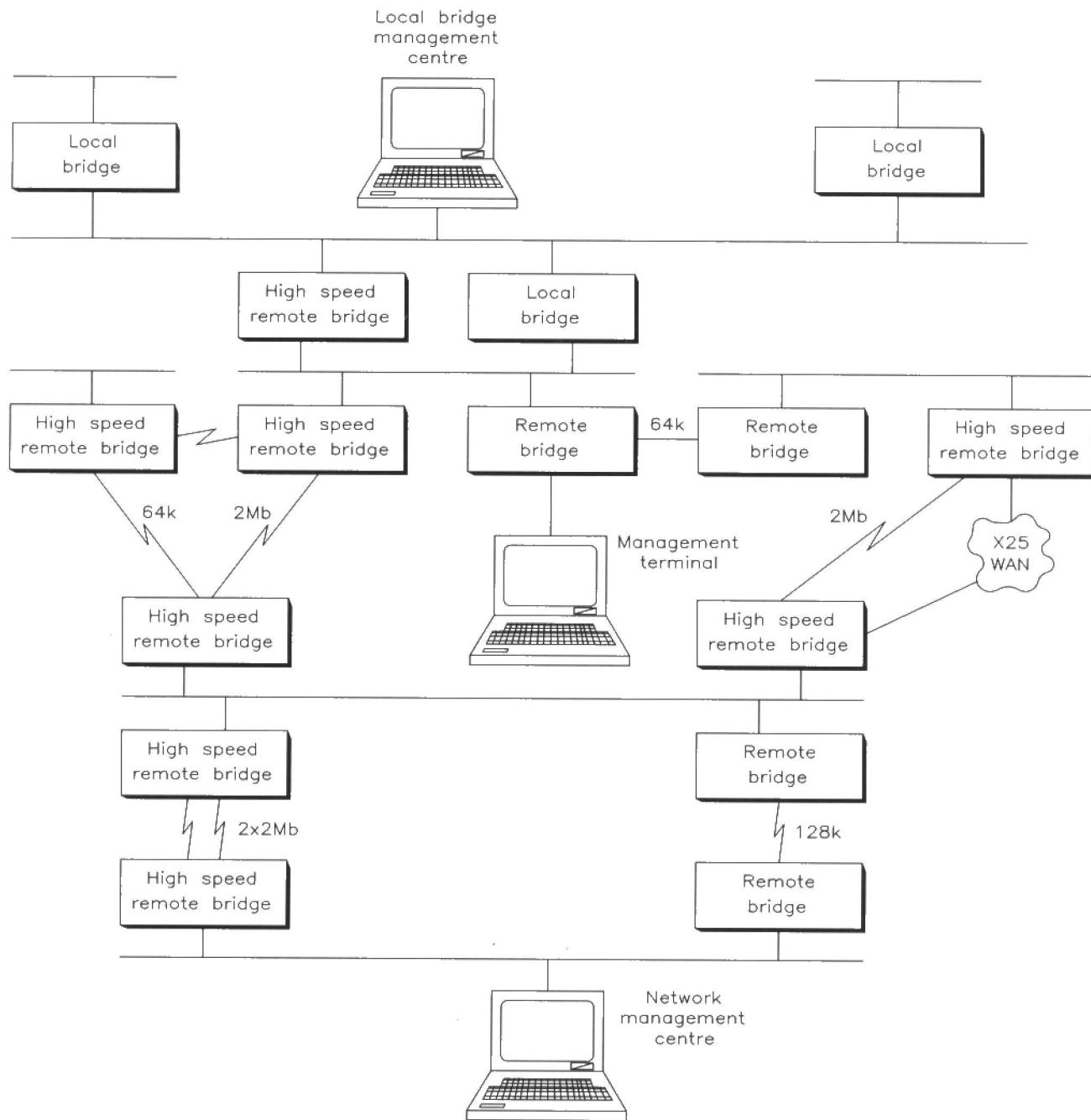


Figure 2. From a simple connection between two LANs to a managed corporate network - the complete solution.

region onto the 'backbone'. The bridge/router is fed by smaller networks or sites which tend to be bridged. By configuring each group of bridged networks as a separate Spanning Tree domain, no single grouping in the network becomes unmanageably large.

Although each local group may have some superfluous multicast traffic, this is not propagated beyond the bridge/router, which acts as a protective barrier for the rest of the network. Similarly, redundant traffic is not imported into any local group, because it does not appear on the 'backbone' network.

This typifies the philosophy behind open networking. An organisation's network is not owned by any one supplier, it is owned by the organisation which pays for the network, as a means of running their business more efficiently.

REPEATERS, BRIDGES, ROUTERS & GATEWAYS

The linking together of LANs which are on the same and/or different sites is often necessary. There are a number of possible ways to do the linking, all of which differ in sophistication and facilities. Gateways, routers, bridges and repeaters all operate at different layers of the OSI model. Repeaters at the physical layer; bridges at the data link layer; routers at the network layer; and gateways at the application layer.

Repeaters provide the simplest option for extending an Ethernet or Token Ring LAN, by regenerating electrical signals and propagating the Ethernet or Token Passing protocols. A number of different types are available for the full range of media used in LANs. Repeaters do not recognise any addressing information and merely pass packets of data between the two inter-connected LANs at their full speed.

Bridges operate totally within the two lower layers of the OSI model outlined in Figure 1. A LAN bridge operates without needing to know or understand any of the higher layers. Bridges are used to interconnect Ethernet and Token Ring LANs, but they are mainly used to

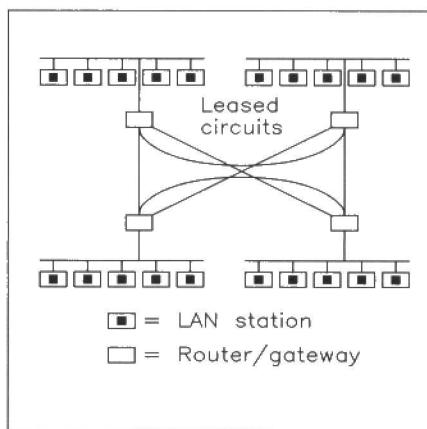


Figure 3. Dedicated leased circuit interconnection.

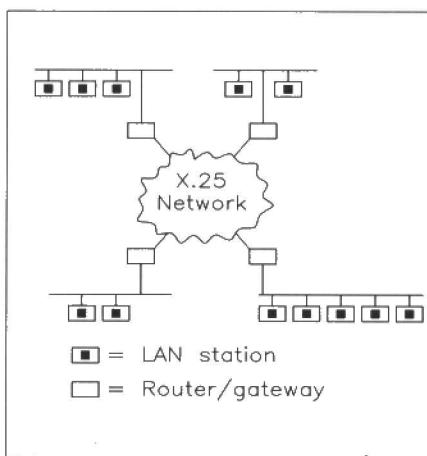


Figure 4. Interconnection via an X.25 network.

connect together LANs of the same type. They are able to interpret the unique addressing information attached to each data packet, and hence act as an address filter to restrict the traffic to the appropriate part of the network, as necessary.

Routers are highly intelligent devices, designed to provide single or multiple connections between LANs or WANs. The LAN types can be dissimilar and a very selective choice can be made dynamically as to the best route, based on cheapest, fastest or any other factor.

Gateways operate at the highest layer of the OSI model and perform

protocol conversion, enabling them to interconnect dissimilar networks. Multiple gateways on a common LAN enable terminals and PCs to switch between applications on diverse and normally incompatible computer systems.

CONNECTIVITY OPTIONS

Connecting together several LANs on geographically dispersed sites into a single homogeneous network is now becoming common practice. As illustrated in Figure 3, this can be achieved by the use of routers and high-speed (64k-bit/s or 2.048M-bit/s) dedicated circuits arranged in a mesh topology network. For a full mesh (full interconnection of all nodes), the number of connecting links required = $N(N-1)/2$ where N = the number of nodes in the network. The number of links (here, dedicated leased circuits) will rise sharply as the number of nodes increases. So a four LAN network requires six connecting circuits, whereas a six LAN network requires 15. In practice a partial mesh, which offers some compromise between expensive leased circuits and full connectivity, is usually employed.

Packet switched WANs (Figure 4) can also be utilised and the solution offers full connectivity, but suffers from the disadvantage that the data rates (typically up to 64k-bit/s) offered by these types of network on the line side are inadequate for the high-speed bursts of data generated by LANs.

Another possibility is N-ISDN, when it becomes widely available. The basic rate service (2×64 k-bit/s) would only be marginally faster than a public packet switched WAN, but primary rate (30 x 64k-bit/s) would offer a significant improvement. However, a circuit switched service like ISDN is not appropriate for dealing with LAN traffic. LANs send data in single high-speed packets. Setting up a call and paying the minimum call charge for a single packet could put ISDN at a serious cost disadvantage for LAN connectivity. It depends on the tariffing structure and speed of setting up a call.



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